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GEOLOGY OF
BITTERWATER CREEK AREA
KERN COUNTY, CALIFORNIA

By **HENRY H. HEIKKILA** and **GEORGE M. MacLEOD**

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By Henry H. Heikkila * and George M. MacLeod **

OUTLINE OF REPORT

Page
ABSTRACT ---------- 3
INTRODUCTION ---------- 3
STRATIGRAPHY ---------- 4
  Jurassic and Cretaceous ---------- 4
  Eocene ---------- 7
    Point of Rocks formation ---------- 7
  Miocene ---------- 7
    Temblor formation ---------- 7
    Monterey formation ---------- 11
  Pliocene-Pleistocene ---------- 14
    Tulare formation ---------- 14
  Pleistocene (?)-Recent ---------- 15
    Terrace gravel and alluvium ---------- 15
STRUCTURE ---------- 15
ECONOMIC PROSPECTS ---------- 19
SUMMARY ---------- 19
REGISTER OF FOSSIL LOCALITIES ---------- 19
ANNOTATED BIBLIOGRAPHY ---------- 20

ILLUSTRATIONS

Figure 1. Index map showing location of area ---------- 4
2. Names of geographic and geologic features in the Bitterwater Creek area ---------- 6
3. "Cannonball" concretions in the Eocene Point of Rocks sandstone in Cedar Canyon ---------- 7
4. Eocene Point of Rocks sandstone as exposed along the axial trace of the First anticline ---------- 8
5. Conglomeratic bed in the Carneros sandstone member of the Temblor ---------- 9
6. Prominent calcareous beds in the Media shale member of the Temblor ---------- 10
7. Steeply dipping, buff colored limestone beds interbedded with siliceous shale in the Media shale member of the Temblor ---------- 10
8. Steeply dipping, fossiliferous beds in the "Button bed" member of the Temblor ---------- 11
9. Limestone bed in the lower part of the McDonald shale member of the Monterey southeast of Bitterwater Creek ---------- 13
10. Relationship between the McDonald shale and the Twisselmann sandstone ---------- 14
11. Miocene overlap of the Cretaceous in Shale Hills ---------- 14
12. Exposure of reverse fault within the Gould-Devilwater shale ---------- 15
13. Oil seep near the Abbot No. 1 well ---------- 15
14. Present distribution of pre-Temblor sediments ---------- 16
15. Present distribution of pre-Monterey sediments ---------- 18
Plate 1. Geologic map of the Bitterwater Creek area ----------6-7
2. Geologic cross-sections of Bitterwater Creek area --14-15

ABSTRACT

The results of a detailed stratigraphic and structural study of approximately 40 square miles in the Temblor Range of northwest Kern County, California, are presented. The sedimentary rocks in the area range in age from Jurassic to Recent; however, great thicknesses of complexly related Miocene sediments of the Temblor and Monterey formations form the stratigraphic units of major importance. Both of these formations are marked by abrupt lateral changes in thickness and lithology. The Temblor is divided into its component members as recognized in the Carneros Creek area. Subdivisions of the Monterey are made on the basis of local usage; a new sandstone member, the Twisselmann, is recognized and named. The principal structural features consist of a series of northwest-trending folds modified by normal and reverse faulting and overturning. These structural features along with favorable stratigraphic conditions combine to make the area of interest for petroleum exploration.

INTRODUCTION

Location of Area. The geology of about 40 square miles in the eastern foothills of the Temblor Range in the northwest part of Kern County, California, is investigated. The area is centered within T. 27 S., R. 18 E., M. D., and includes parts of the adjoining townships. It is reached by U. S. Highway 466 via Paso Robles or Blackwell's Corner. Numerous dirt roads also traverse the area and allow easy access. Topographic maps which cover the area are the Army Map Service quadrangles entitled Shale Point, Emigrant Hill, Sawtooth Ridge, and Packwood. These maps are available on a scale of either 1:31,680 or 1:25,000.

Purpose and Scope of Report. The area covered by this report is of particular geological importance as it is located within a major petroleum producing region. Field work, therefore, was conducted with the primary aim of determining and interpreting stratigraphic and structural relations with regard to possible oil and gas accumulation. Subsurface information from wells drilled within the area or adjacent to it has been coordinated with the surface geology. Data from wells drilled subsequent to the original field work have been incorporated into this report and revisions have been made in the text and maps to be in accord with the new information.

Field Work and Methods. Approximately three months in the summer of 1947 were spent in field mapping. The plotting of geologic data was done simultaneously on aerial photographs and on topographic maps. Stratigraphic sections were measured by plane table traverses; microfossil samples were collected concurrently.

Previous Work. The results of previous work in the area by the United States Geological Survey have been published by Arnold and Johnson [1] and by English.[2] Other investigations have been and are still being made by numerous oil companies, although very few of the results have been put in published form. The annotated bibliography included with this report represents a fairly complete coverage of the pertinent geologic literature.

Interest in this area is evidenced by the numerous dry holes drilled over the period of the past 30 years. The production obtained in the adjacent Blackwell's Corner field represents the closest production obtained to date. Nevertheless, the area can still be considered as decidedly active.

Acknowledgments. Complete financial support for the expenses incurred during the period of field work as well as in the preparation of the original theses was provided by the Honolulu Oil Corporation of San Francisco, California. Thanks are due to Mr. Elmo W. Adams, Chief Geologist for Honolulu Oil Corporation at the time the major part of the work was done, to Mr. John H. McMasters, present Chief Geologist, and to Messrs. Charles E. Cross, Paul E. McGovney, and Floyd L. Johnson, geologists, Honolulu Oil Corporation. Dr. Siemon W.

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† Unpublished Master's theses, Stanford University, 1948. Manuscript submitted for publication June 22, 1950.

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[1] Arnold, Ralph, and Johnson, Harry R., Preliminary report on the McKittrick-Sunset oil region, Kern and San Luis Obispo Counties, California: U. S. Geol. Survey Bull. 406, pp. 11-225, 1910.

[2] English, Walter A., Geology and petroleum resources of northwestern Kern County, California: U. S. Geol. Survey Bull. 721, pp. 5-226, 1921.

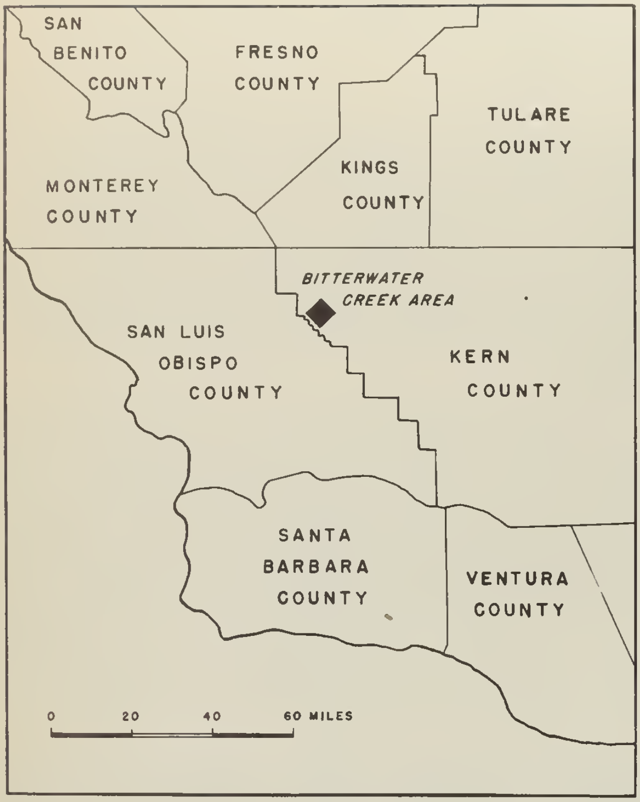


Fig. 1. Index map showing location of area.

Muller, Professor of Geology, Stanford University, furnished guidance both in the completion of the field work and in the compilation of the report. Professor A. Irving Levorsen, Stanford University, was instrumental in initiating the original project. Appreciation is also expressed to the Standard Oil Company of California for providing housing facilities at its Bitterwater Creek Pumping Station, and to Mr. Walter Paap, geologist, Standard Oil Company of California, for his timely suggestions in the field. Paleontological determinations were made by Carlos E. Key of Stanford University.

STRATIGRAPHY

The sediments present range in age from Jurassic to Recent. From an economic viewpoint, the Cretaceous rocks are generally considered as the basement in this area so that Eocene and Miocene sediments are those of primary interest. In general, the Tertiary sediments are marked by many sharp lateral changes in both thickness and lithology. Rapid vertical changes are also characteristically numerous. The stratigraphic nomenclature used in this report as compared with that employed by previous authors is shown in table 1. It will be noted that the nomenclature currently used for subdivisions of the Temblor is based principally on the type section of the Temblor as exposed in the Carneros Creek area. The subdivisions of the Monterey are based for the most part on common usage in adjacent localities.

Jurassic and Cretaceous

The pre-Tertiary rocks in the area are considered to be of slight importance as potential commercial oil or gas producers; therefore, they are not discussed in detail. The Jurassic is represented in an isolated occurrence of serpentine and red and green chert, projecting through Cretaceous rocks and partially concealed by Plio-Pleistocene Tulare sediments. The Jurassic outcrop is located in secs. 33 and 34, T. 27 S., R. 18 E., and secs. 3 and 4, T. 28 S., R. 18 E.

The Cretaceous rocks have a greater areal exposure and consist of 4800+ feet of undifferentiated olive-drab shale, sandstone, and thin beds of limestone. They crop out in and to the west of Cedar Canyon on the overturned west flank of the Cedar Canyon syncline and also form the exposed core of the Raven Pass anticline. A small area of outcrop is located in secs. 21 and 28, T. 26 S., R. 18 E. Ammonites including *Baculites* (L.S.J.U. Loc. No. 2849), collected from a conglomeratic bed in this vicinity indicate that the sediments are of Upper Cretaceous age. One *Baculites* cf. *B. chicoensis* Trask (L.S.J.U. Loc. No. 2848), was found in the Raven Pass anticline area. The Cretaceous age of the rocks to the southwest of and along Cedar Canyon is based on lithologic similarity to those along the Raven Pass anticline.

Table 1

TABLE OF STRATIGRAPHIC TERMINOLOGY

	ARNOLD & JOHNSON, 1910	ENGLISH, 1921	THIS REPORT, 1950	
RECENT	ALLUVIUM & TERRACE DEPOSITS	ALLUVIUM & TERRACE DEPOSITS	ALLUVIUM & TERRACE DEPOSITS	
PLEISTOCENE	MC KITTRICK FORMATION	MC KITTRICK FORMATION	TULARE FORMATION	
PLIOCENE				
UPPER MIOCENE			MONTEREY FORMATION	MC DONALD SHALE ★TWISSELMANN SANDSTONE GOULD(?)-DEVILWATER SHALE
MIDDLE MIOCENE	SANTA MARGARITA (?) FORMATION MONTEREY FORMATION	MARICOPA SHALE & VAQUEROS SANDSTONE UNDIFFERENTIATED	TEMBLOR FORMATION	"BUTTON BED" SANDSTONE
LOWER MIOCENE	VAQUEROS SANDSTONE & UNDIFFERENTIATED MIOCENE			MEDIA SHALE CARNEROS SANDSTONE UPPER SANTOS SHALE AGUA SANDSTONE
OLIGOCENE	OLIGOCENE (?) ROCKS	OLIGOCENE (?) ROCKS		
EOCENE	TEJON FORMATION	TEJON FORMATION	POINT OF ROCKS FORMATION	
CRETACEOUS	KNOXVILLE-CHICO ROCKS ?	SHASTA-CHICO ROCKS ?	UNDIFFERENTIATED ?	
JURASSIC	FRANCISCAN FORMATION	FRANCISCAN FORMATION	UNDIFFERENTIATED	

★ NEW NAME

Table 2. Summary of exposed formations

Age		Formation or member		Symbol	Thickness	Description
RECENT			Alluvial & Terrace Gravels	Qal	0-?	Unsorted alluvial material.
PLEISTOCENE PLIOCENE			Tulare	QTt	0-400?	Unsorted debris from older formations.
UPPER MIOCENE	Mohnian	Monterey formation	McDonald shale	Tmm	2500	Porcelaneous and siliceous shale with beds of buff-yellow concretionary limestone. Some soft, fissile, silty, siliceous shale. Diatomaceous in part. Silty with sandstone beds near base.
			Twisselmann sandstone	Tmt	0-2200?	Friable silty to medium-grained sandstone, generally gray in color but locally rust mottled to tan. Finer and more silty near top. Two shale beds in upper half. Bioclastic reef at base.
MIDDLE MIOCENE	Luisian		Devilwater - Gould shale	Tmgd	0-1500	White to gray, soft platy silty shale with some porcelaneous shale and some buff-yellow limestone beds. Characterized by flood of Valvulineria californica. Hard platy, partly silicified and locally tan cherty shale at base.
	Relizian	Temblor formation	"Button bed" sandstone	Ttb	0-800	Fine- to medium-grained buff sandstone with hard calcareous bioclastic conglomeratic beds containing numerous pecten shells.
LOWER MIOCENE	Saucesian		Media shale	Ttm	0-1800	Tan platy calcareous silty shale with sandstone beds in basal part; white-weathering hard blocky siliceous shale in middle and upper part. Characterized by numerous hard buff limestone beds particularly in middle of section.
			Carneros sandstone ?	Ttc	0-1250	Lumpy nodular, massively-bedded, gray medium to fine-grained sandstone. Locally friable and massive, or hard, platy, calcareous sandstone. Some fossiliferous conglomeratic lenses.
			Upper Santos shale	Ttus	0-1500	Tan platy, siliceous and calcareous silty to sandy shale with some discontinuous thin limestone and sandstone beds.
	Zemorrian		Agua sandstone	Tta	0-48	Gray to buff, fine to medium-grained friable sandstone. Abundant fragments of pectens.
EOCENE			Point of Rocks sandstone	Tpr	0-600	Brown to white, coarse- to medium-grained friable sandstone characterized by large red-brown "cannon ball" concretions. Abundant muscovite flakes.
CRETACEOUS			Undifferentiated	Ku	5000	Interbedded olive-drab clay shale and fine-grained to silty calcareous sandstone. Fossil ammonites including Baculites.
JURASSIC			Undifferentiated	Ju	?	Serpentine, red and green chert.

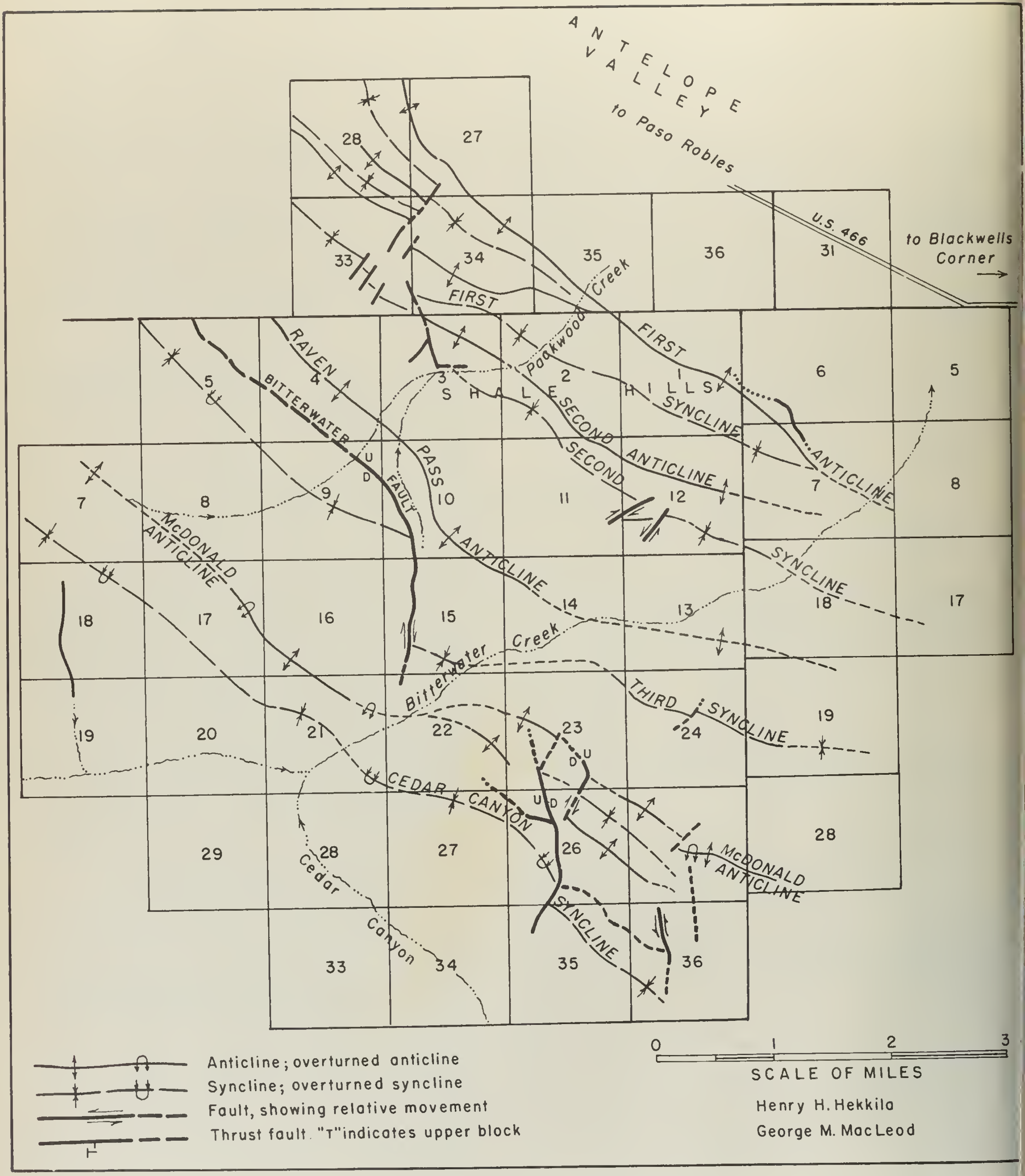
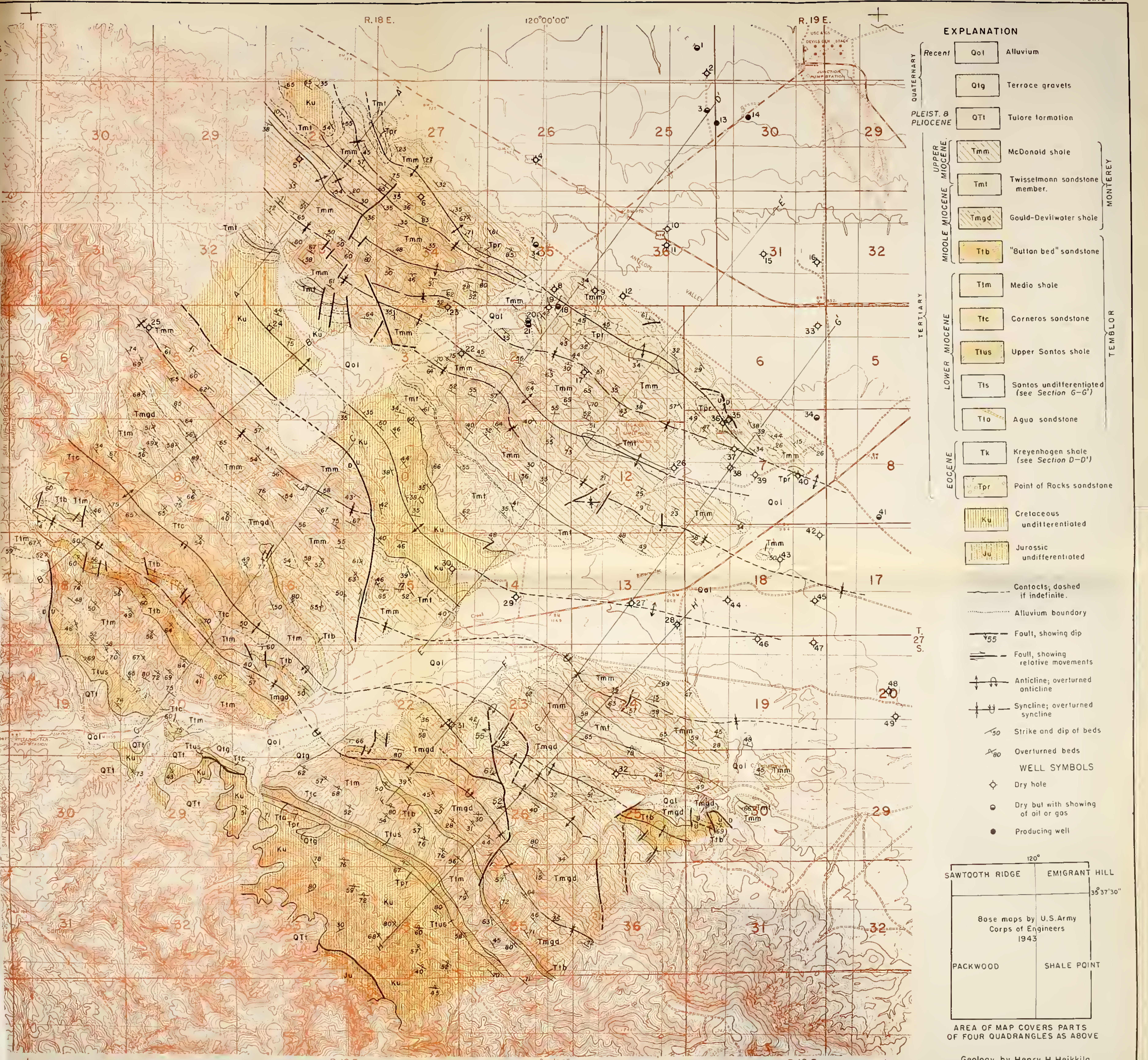


FIG. 2. Names of geographic and geologic features in the Bitterwater Creek area.



Geology by Henry H. Heikkila
and George M. Mac Leod

TOPOGRAPHIC AND GEOLOGIC MAP OF THE BITTERWATER CREEK AREA, KERN COUNTY, CALIFORNIA

1 ½ 0
SCALE OF MILES
CONTOUR INTERVAL 25 FEET

Eocene

Point of Rocks Formation

The Point of Rocks formation is exposed along the northeast side of Cedar Canyon unconformably overlying the Cretaceous rocks. At the mouth of Cedar Canyon where it joins Bitterwater Creek, a maximum thickness of 600 feet is exposed. Southeastward along the strike there is a gradual decrease in apparent thickness due to the progressive overlapping of the sandstone by the overlying upper Santos shale, until the sandstone completely disappears in the northeastern part of sec. 34, T. 27 S., R. 18 E. In portions of the Cedar Canyon section, the Point of Rocks is difficult to distinguish from the discontinuous sandstone lenses within the overlying upper Santos shale.

In the Shale Hills the Point of Rocks is exposed along the axial trace of the First anticline (fig. 2) at Shale Point and in the vicinity of the Rio Grande Oil Company's well, Utting No. 1, in the northwest part of sec. 7, T. 27 S., R. 18 E. It is present also from east-central sec. 1, T. 27 S., R. 18 E., northwesterly to Packwood Creek, and in isolated outcrops along the northwesterly continuation of the First anticline north of Packwood Creek. Along the First anticline, the Point of Rocks is overlain with apparent disconformity by the McDonald shale member of the Monterey formation, with the exception of the exposure in sec. 27, T. 26 S., R. 18 E., where it is overlain by the Twisselmann sandstone member of the Monterey formation. The average thickness of the Point of Rocks sandstone in the Shale Hills vicinity is difficult to determine. In sec. 7, T. 27 S., R. 18 E., well logs give an approximate thickness of 200 feet; the Superior Oil Company's Ryan No. 1 well in the southwest corner of sec. 36, T. 26 S., R. 18 E., encountered 1900 feet of Point of Rocks. The northwesternmost exposure of the Point of Rocks is in sec. 27, T. 26 S., R. 18 E.; its northern limit of subsurface control is in sec. 26, T. 26 S., R. 18 E., where the Continental Oil Company's well Mabury No. 3 logs Eocene Point of Rocks sandstone overlying the Domengine sandstone. As the Cretaceous is in contact with the Miocene Twisselmann sandstone in sec. 28, T. 26 S., R. 18 E., it is concluded that the Point of Rocks sandstone is wedged out completely to the northwest in Antelope Valley, where it probably is truncated by either the McDonald shale or Tulare sediments.

In all its occurrences the Point of Rocks formation is a coarse- to medium-grained sandstone characterized by the presence of numerous red-brown ''cannonball'' concretions of calcarinate sandstone up to 4 or 5 feet in diameter. Outcrops consist of massive, porous, poorly sorted, cavernous, arkosic sandstone with no apparent bedding. Colors are light gray and gray to tan on fresh surfaces. Commonly the rock weathers to hues of red and red-brown. Mineralogically, the sandstone consists of angular and some subangular grains of quartz, plagioclase, orthoclase, dark chert, unidentified ferromagnesian minerals and biotite flakes. The leaching of the calcium carbonate cement produces a light-colored friable sandstone. The remaining interstitial material is commonly white and chalky in appearance and is present in the sandstone at all outcrops. Joints are irregular and are filled with calcareous material. Outer surfaces of the friable portions are locally indurated or ''case-hardened''.

In Cedar Canyon, the Eocene sandstone has been mapped previously as the Tejon formation. In the Shale Hills, the sandstone and shale previously mapped as Vaqueros and Maricopa, respectively, were both included by English[3] in a single undifferentiated unit. Of this undifferentiated unit, the sandstone overlying the Cretaceous on the east flank of the Raven Pass anticline is Miocene, whereas the sandstone exposed in the First anticline in the Shale Hills is thought to be the Eocene Point of Rocks. Identification of the latter sandstone as the Point of Rocks is based on lithological and mineralogical characteristics. The distinctive ''cannon ball'' concretions and cavernous character of the exposures permit correlation of the sandstone in the First anticline with the Eocene rocks exposed in Cedar Canyon, with those in the southeast part of sec. 31, T. 27 S., R. 19 E., along the axial trace of the McDonald anticline, and with those at the Point of Rocks in T. 26 S., R. 18 E., the type locality of the Point of Rocks formation.

Miocene

Temblor Formation

The Temblor formation as such is traceable from its type locality at Carneros Creek northward to Bitterwater Creek. In places, however, the lithologic identity of the various members, particularly the sandstones, is doubtful or obscure due to changes in facies and because of soil cover. The use of the names upper Santos shale,[4] Carneros sandstone,[5] Media shale,[6] and ''Button bed'' sand-

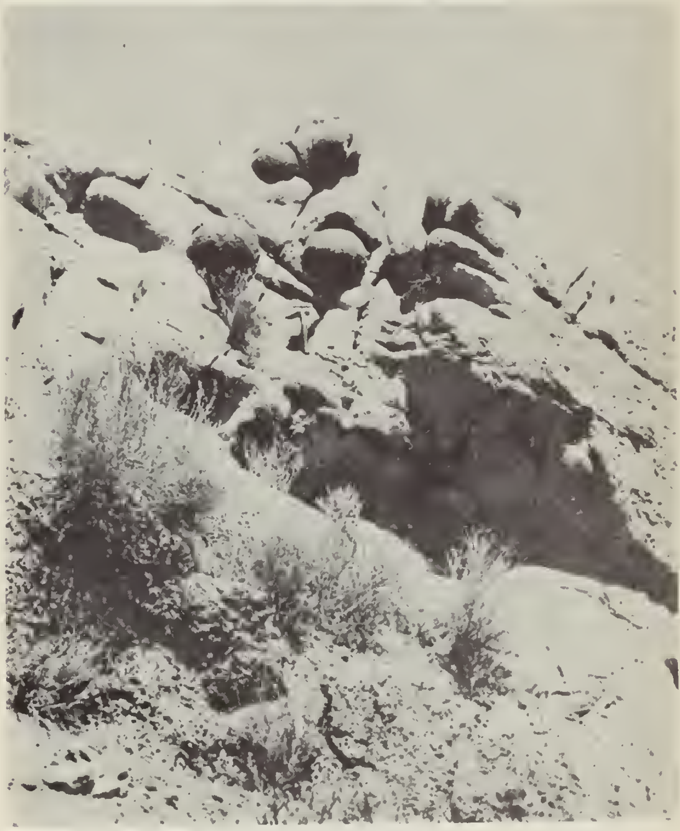


Fig. 3. "Cannonball" concretions in the Eocene Point of Rocks sandstone in Cedar Canyon. Hammer indicates scale.

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[3] English, W. A., op. cit.

[4] Gester, G. C., and Galloway, John, Geology of the Kettleman Hills oil field, California: Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 10, fig. 3, pp. 1159, 1933.

[5] Cunningham, G. M., and Barbat, W. F., Age of the producing horizon at Kettleman Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 16, no. 4, pp. 419-421, 1932.

[6] Op. cit.

stone,[7] nevertheless is justified by the fact that the shale members contain foraminiferal assemblages characteristic of the same units in their type areas. The type Carneros sandstone is at Carneros Creek, and although never so designated formally, the type localities of the Santos and Media shales are presumably at the nearby Santos and Media Agua Creeks respectively.

The lowest exposed member of the Temblor in this area is the Agua sandstone. In this connection Clark[8] states:

> "Vaqueros fossils, including *Ostrea vaquerosensis* and *Pecten magnolia*, have recently been found at several localities in a sandstone member occuring in the upper part of the Santos shale. This sandstone member, here referred to as the 'Agua sandstone', is traceable from the vicinity of Carneros Creek to the mouth of Cedar Canyon, several miles farther northwest, and, in places, reaches a thickness of more than 300 feet."

In Cedar Canyon, the Agua sandstone is in apparent conformity with the upper Santos shale. The lower Santos shale does not crop out in the area.

It is not possible to trace the "Button bed" from the type locality at Carneros Creek to the Bitterwater Creek area as it disappears under soil cover[9] in the northwest corner of sec. 17, T. 28 S., R. 19 E. Foraminiferal data from the underlying shales in the area, however, place the uppermost Temblor sandstone in the same stratigraphic position as the type "Button bed". The use of the name "Button bed" in the Bitterwater Creek area, therefore, is thought to be valid.

The Temblor formation as exposed in the Bitterwater Creek area is composed of a variety of sandstones and shales with numerous intermediate gradations both vertically and horizontally. Deposition took place under continually changing conditions, producing diversified sediments. Frequently, repetition of a particular set of conditions has resulted in the presence of identical strata at different stratigraphic horizons. The sediments range from porcelaneous shale to fine-grained sandstone and to coarse, gritty sandstone with conglomeratic lenses. The contacts between the different members are commonly gradational and are complicated by rapid changes in thickness due to sudden lateral variations. There is a marked thickening of all members of the Temblor cropping out in the area immediately northwest of Bitterwater Creek. Although faunal control is fairly satisfactory the absence of foraminifers in many places in the shales hampers precise correlation on a zone level.

Agua Sandstone Member. Unconformably overlying the Point of Rocks sandstone are 48 feet of the Agua sandstone. This is the maximum thickness exposed at the mouth of Cedar Canyon. To the southeast, along Cedar Canyon, the sandstone is overlapped by upper Santos shale. For 1000 feet along the strike, from its northwesternmost exposure at the mouth of Cedar Canyon, the Agua sandstone has a basal $\frac{1}{2}$- to 1-foot thick bed of a gritty texture, characterized by *Pecten magnolia* Conrad, *Pecten perrini?* Arnold, and fragments of oysters. The sandstone consists of medium to coarse, subangular grains of quartz and orthoclase as well as rounded grains of dark chert. Abundant muscovite and glauconite distinguish the Agua sandstone from the underlying Point of Rocks sandstone.

In the south-central part of sec. 30, T. 27 S., R. 19 E., in the McDonald anticline, a bioclastic bed which contains *Pecten magnolia* Conrad locally overlies the Point of Rocks formation. It has also a lithology similar to that of the Agua sandstone in Cedar Canyon, and therefore may possibly be identified as the Agua. Data from the Signal-Honolulu Oil Company's No. 1 and 2 Carpenter wells in sec. 6, T. 28 S., R. 19 E., indicate that the upper Santos shale, Carneros sandstone, and Media shale are transgressed by the "Button bed" sandstone. The Agua sandstone is believed to overlie the Point of Rocks uninterruptedly from Cedar Canyon to the McDonald anticline and is not truncated by the "Button bed" sandstone as are the intervening Temblor members.

Upper Santos Shale Member. At the mouth of Cedar Canyon, 274 feet of the upper Santos shale conformably overlie the Agua sandstone. At the base immediately above the Agua, there is an estimated thickness of 25 to 50 feet of chocolate-brown to dark gray clay shale. The clay shale is overlain by thinly laminated, locally silty, tan, porcelaneous shale which makes up the remaining thickness of the upper Santos. The lower clay shale has poor exposures in gullies and its soil consists of small, light gray chips. In contrast, the upper porcelaneous shale is hard and platy, and has well-exposed outcrops. Lenses of dense, rusty-brown limestone, 1 foot to 2 feet thick, appear at stratigraphic intervals of 10 to 20 feet in the upper platy shale; in addition, lenses of sandstone from 10 to 15 feet in thickness are also interbedded with the upper shale. Though discontinuous, these lenses may be traced for several hundred feet before they disappear. Usually at least two sandstone lenses are present. They consist of medium-sized angular grains of quartz, feldspar, and a minor amount of chert. The sorting is fair. Mineralogically, the lenses of sandstone are distinguished from the Point of Rocks formation, wherever the two are in contact, by the lack of biotite in the upper Santos.

The Carneros sandstone member pinches out as it crosses Bitterwater Creek northwestward, and the means of separation of the upper Santos shale from the Media shale is lost. Aside from meager foraminiferal data, there are not certain lithologic criteria to distinguish the upper Santos from the Media on the northwest side of Bitterwater Creek. From the Tulare overlap in secs. 18 and 19, T. 27 S., R. 18 E., northeastward to the outcrop of the

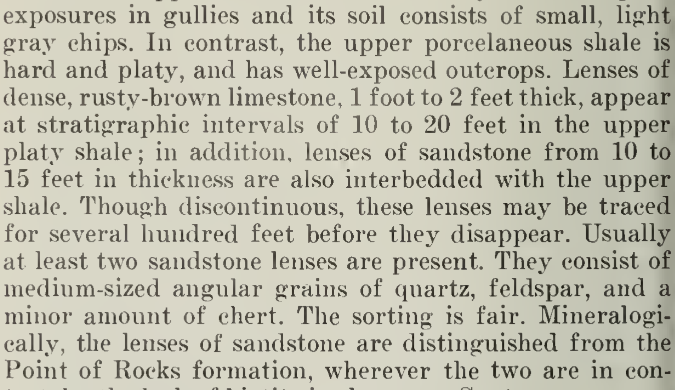

Fig. 4. Eocene Point of Rocks sandstone as exposed along the axial trace of the First anticline in sec. 1, T. 27 S., R. 18 E.

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[7] Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 3d ser., vol. 2, no. 2, 1905.

[8] Clark, L. M., and Clark, Alex, The Vaqueros in the Temblor Range (abst): Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 1, p. 137, 1935.

[9] Parsons, Kenneth R., The Texas Company, oral communication.

"Button bed" sandstone on the west flank of the Cedar Canyon syncline, the combined thickness of the upper Santos and Media shales is approximately 3500 feet; from the Tulare overlap to the projected outcrop of the Carneros sandstone in the west central portion of sec. 20, the maximum exposed thickness of the upper Santos shale is about 1500 feet. Thus, there is an unusual disparity in the thickness of the upper Santos shale between outcrops south of Bitterwater Creek where the maximum exposed thickness of the upper Santos is 274 feet and those north of Bitterwater Creek. A large part, if not all, of the upper Santos as well as much of the Media shale in the area immediately northwest of Bitterwater Creek in secs. 18, 19, and 20 grades laterally into the Carneros sandstone as it appears nearby to the northeast along the axial trace of the McDonald anticline.

Carneros Sandstone Member. The Carneros sandstone member conformably overlies the upper Santos shale and is in turn conformably overlain by the Media shale. At the mouth of Cedar Canyon it attains a thickness of 123 feet. About a mile southeastward it is 103 feet thick and in the northwest part of sec. 34, T. 27 S., R. 18 E., it is 88 feet thick. From this point southeastward along the strike the thickness is difficult to determine because the fine sandstone at the top is poorly exposed and apparently grades into the overlying Media shale. Southeastward through secs. 34 and 35, T. 27 S., R. 18 E., the Carneros becomes discontinuous. It is impossible to tell whether this is due to lenticularity of the sandstone or to overlap by the Media shale. Lenticularity is thought to be the most likely explanation. Northwestward from the mouth of Cedar Canyon, the Carneros sandstone extends across Bitterwater Creek from secs. 28 and 29 to sec. 20, where it disappears in an apparent lateral gradation into the upper Santos and Media shales.

Along the axial trace of the McDonald anticline through secs. 7, 8, and 17, T. 27 S., R. 18 E., the Carneros sandstone has a minimum exposed thickness of 1250 feet. As no sediments underlying the Carneros crop out along the axial trace of this anticline, it is impossible to determine just how thick the Carneros actually is in this part of the area. As the maximum thickness exposed in the adjacent Cedar Canyon section is only 123 feet, the sudden change in thickness is striking and is probably due to a rapid change in facies. A large part of the Media and upper Santos shales present on the southwest flank of the Cedar Canyon syncline, secs. 18, 19, and 20, T. 27 S., R. 18 E., changes laterally into the Carneros sandstone as shown by the decrease in the thickness of the Media shale between its outcrops on the southwest limb of the Cedar Canyon syncline and its exposures on the flanks of the McDonald anticline and by the different lithologies present in the sandstone composing the Carneros outcrops along the axial trace of the McDonald anticline.

The most common lithologic type is a very hard, medium- to fine-grained calcarinate tan to gray sandstone. Nearly all of the outcrops of this sandstone have a lumpy, nodular character resulting from the brecciation of the rock during deformation. Recementation by calcareous material has produced an indurated and resistant rock. A second type of sandstone is essentially the same except for the lack of a calcareous cementing material. Outcrops consist of buff-colored friable sandstone. A third type consists of well-bedded, fine-grained to silty, buff calcarinate sandstone which weathers into tan, platy fragments resembling the tan shale of the upper Santos. Fossiliferous beds in the Carneros of the McDonald anticline have an irregular stratigraphic occurrence. Many of them contain fragments of unidentified echinoderms, pectens, and oysters as well as pebbles of quartz, dark chert, and fractured, rusty-brown limestone imbedded in a matrix of medium- to coarse-grained sandstone. Holes bored by mollusks and subsequently filled by sand are common in the limestone pebbles, and indicate near-shore conditions of deposition. Mineralogically, the Carneros sandstone consists of quartz, feldspar, occasional muscovite flakes, and a minor amount of indeterminate dark grains.

Media Shale Member. The Media shale member of the Temblor formation conformably overlies the Carneros and apparently is conformably overlain by the "Button bed" sandstone. Prominent outcrops of the unit are present on the southwest flank of the Cedar Canyon syncline. Additional outcrops flank the McDonald anticline northwest of Bitterwater Creek. The Media varies greatly in thickness; outcrops on the southwest flank of the Cedar Canyon syncline have a measurable thickness of 1500 to 2300 feet. Outcrops bordering the Carneros along the McDonald anticline are 500 to 800 feet thick.

Lithologically, the Media ranges from tan, platy, silty shale to light-colored, hard, porcelaneous and siliceous shale. Generally there is a gradual lithologic change upward from the upper Santos through the Media. The sandstone lenses common in the lower portion of the Media and upper Santos disappear, and there is a decrease in the amount of sandy and silty shale. Higher in the Media section the sandstone lenses are displaced by conspicuous limestone beds. The shale becomes predominantly siliceous with variations of off-white, blocky, porcelaneous shale and gray, platy, silty shale. On fresh surfaces, the platy shale often appears light violet or purple. Lithologically the siliceous shale in the upper part of the Media is identical with shale found in the McDonald member of the Monterey. The increased siliceous character and hardness of the Media toward the top of the section results in an increased resistance to weathering which is perhaps indicated by the rise in topography northeastward from the base to the top of the shale.

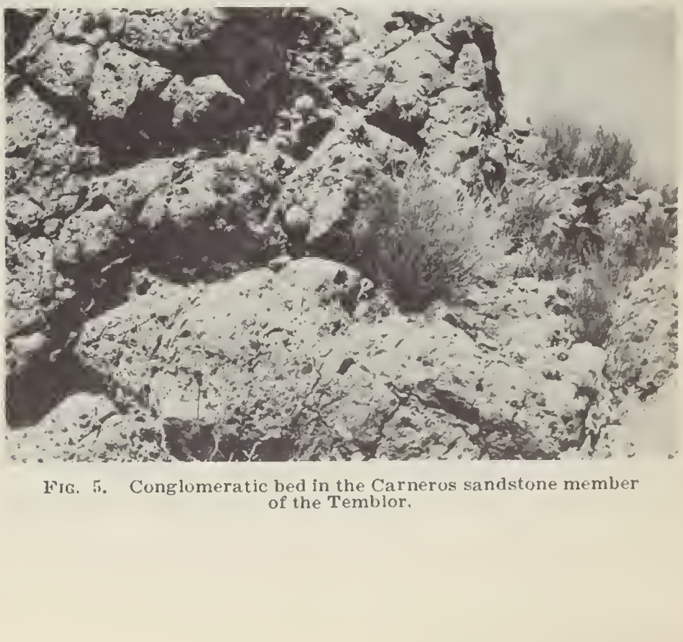

Fig. 5. Conglomeratic bed in the Carneros sandstone member of the Temblor.

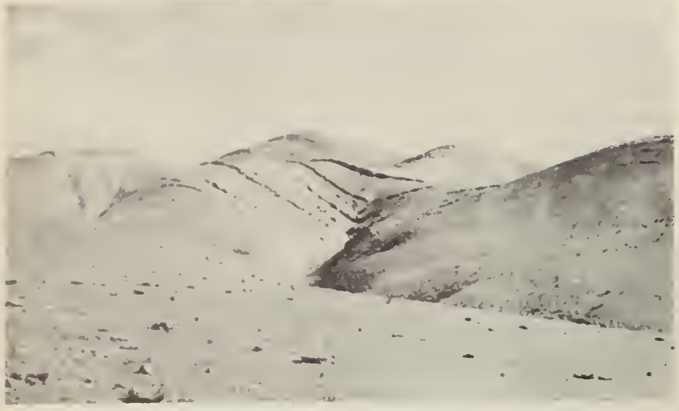

FIG. 6. Prominent calcareous beds in the Media shale member of the Temblor. The distance from left to right in the middle of the illustration is approximately 1300 feet.

The most characteristic lithologic feature of the Media is the presence of numerous hard, rust and buff-colored limestone beds. The limestone beds average about 3 feet in thickness and occur predominantly in the middle third of the section at stratigraphic intervals of 15 to 20 feet. They range from almost pure limestone to very sandy limestone; silty limestone is the most common. The beds stand out prominently and are valuable as structural and stratigraphic markers even though they are not individually continuous for any great distance along the strike.

Diatoms and foraminifers, although not very abundant, are present throughout the Media shale so that faunal control may be considered fair. In the upper third of the section the foraminifers have been leached out so that only external molds are left. An attendant silicification of the shale appears to be associated with the leaching, for wherever there are only impressions of foraminifers the shale is harder and more porcelaneous. In the basal part of the Media in sec. 20, T. 27 S., R. 18 E., a coarse-grained and pebbly sandstone lens was found that yielded numerous pelecypod fragments as well as two specimens of *Turritella ocoyana* Conrad.

The contacts between the Media shale and the Carneros sandstone and between the Media shale and the "Button bed" sandstone are generally fairly distinct. Where the "Button bed" sandstone is absent, as in sec. 8, T. 27 S., R. 18 E., the contact between the Media shale and the shales of the Monterey formation has been drawn on foraminiferal evidence combined with projection along the strike of the last occurrence of the "Button bed" sandstone. The contact between the Media and the upper Santos where the Carneros is absent has been determined in the same manner. Where the intervening sandstone members are absent there is often little or no lithologic evidence to delineate between the different shale units of the Temblor and the Monterey formations.

"Button Bed" Sandstone Member. The "Button bed" sandstone is the youngest member of the Temblor formation present in the area. It overlies the Media shale with apparent conformity and is overlain similarly by the shales of the Monterey formation. There is no field evidence to indicate an unconformity between the Media shale and the "Button bed" sandstone; the contact between the two members is generally clear and well-defined. In addition, there is no indication of divergence between the upper Media limestone beds and bedding in the "Button bed" sandstone. Nevertheless, data from wells in sec. 6, T. 27 S., R. 19 E., slightly to the southeast of the area covered by this report, show that the "Button bed" sandstone is a highly transgressive unit which overlaps the Media and other underlying members of the Temblor. Additional evidence for this is found in secs. 30 and 31, T. 27 S., R. 19 E., where, with the exception of localized outcrops of the Agua sandstone, the "Button bed" is found resting directly upon the Eocene Point of Rocks formation. This "Button bed" sandstone member has the same stratigraphic position as the type "Button bed" sandstone of the Carneros Creek section; however, it differs somewhat in lithology and in faunal content principally by the absence of fossil echinoderms, which are the "buttons" characteristic of the member at its type locality.

Outcrops of the sandstone are present on both flanks of the Cedar Canyon syncline and, in part, on the northeast flank of the McDonald anticline. In these outcrops, the thickness ranges from a knife edge to 800 feet. The thickest section is present on the southwest limb of the Cedar Canyon syncline through secs. 17, 20, and 21, T. 27 S., R. 18 E. The "Button bed" member is not persistent but pinches out and reappears in a number of places. Surface outcrops are missing completely northwest of Packwood Creek on the northeast limb of the McDonald anticline. The last occurrence to the northwest along the strike is a small lens about 60 feet thick cropping out in Packwood Creek in the southeast quarter of sec. 8 T. 27 S., R. 18 E.

On the flanks of the Cedar Canyon syncline in sec. 21, as well as in the Cedar Canyon section to the southeast, the "Button bed" consists of friable to moderately well-consolidated, buff-colored, fine- to medium-grained sandstone with occasional round sandstone concretions. In hand examination quartz alone can be identified; but microscopic examination reveals quartz, orthoclase, and plagioclase in about equal porportions, a minor amount of muscovite and glauconite, and occasional highly altered remnants of ferromagnesian minerals. In portions of the Cedar Canyon section there is a large amount of shell material in the basal part of the sandstone.

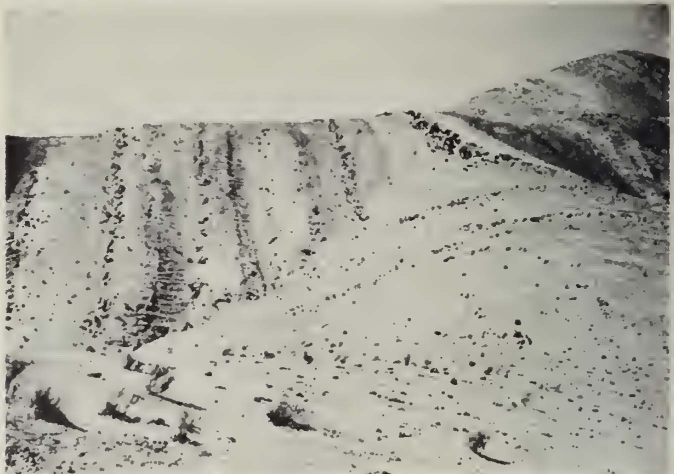

FIG. 7. Steeply dipping, buff-colored limestone beds interbedded with siliceous shales in the Media shale member of the Temblor. These limestone beds are from 2 to 4 feet thick.

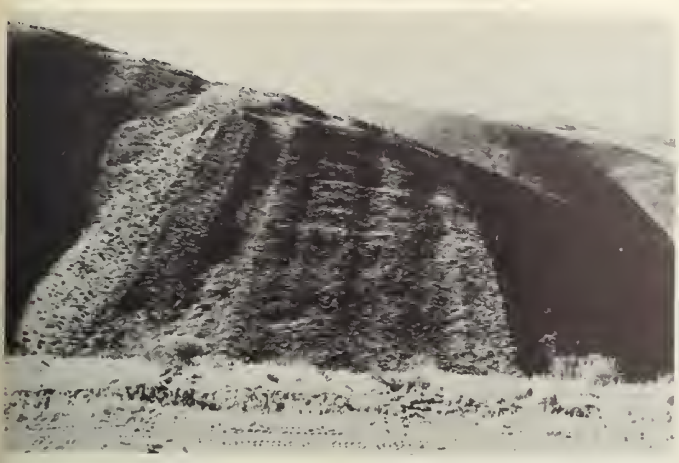

Fig. 8. Steeply dipping, fossiliferous beds in the "Button bed" member of the Temblor in sec. 17, T. 27 S., R. 18 E. The horizontal distance across the outcrop area lighted by the sun is approximately 600 feet.

Northwest along the strike from the outcrops, the sandstone undergoes a change in facies with the development of several fossiliferous, gritty to conglomeratic beds interbedded with the soft, buff-colored sandstone. These fossiliferous beds are very hard, form prominent outcrops, and range from 15 to 35 feet in thickness. They are coarse-grained to pebbly in texture and contain numerous shale, limestone, and chert fragments averaging about a quarter of an inch in diameter with some as much as 2 inches in diameter.

Perhaps the most characteristic feature of these fossiliferous beds in the "Button bed" sandstone is the presence of numerous poorly preserved valves of large pectens. These shells are often oriented with the bedding with their convex side up. In addition small gastropods are present as well as specimens of *Pecten (Aequipecten) andersoni* Arnold. Several outcrops of the friable buff-colored sandstone of the Cedar Canyon section are very fossiliferous.

Monterey Formation

The "Button bed" sandstone is overlain conformably by at least 4000 feet of upper middle and upper Miocene shales and sandstone which are included in the Monterey formation. In various parts of California, middle and upper Miocene strata, which consist predominantly of siliceous shale, have been demonstrated to be so much alike that the term Monterey formation may safely be applied to these rocks in most localities. The siliceous shales of this area have been assigned to the Monterey formation as recommended by Bramlette.[10] The names of mappable members within the Monterey, however, are retained for discussion purposes. Two shale units of the Monterey formation are recognized and differentiated—the Gould-Devilwater shale and the McDonald shale. A third unit, for which the name Twisselmann sandstone is proposed, is present as a large sandstone lens occupying a stratigraphic position equivalent in part to the lower McDonald and the upper Gould-Devilwater.

The Monterey formation conformably overlies the Temblor and is unconformably overlain by the Plio-Pleistocene Tulare formation. There is considerable overlap, however, of the McDonald shale member of the Monterey over the older sediments. The fact that the McDonald and Twisselmann members are in contact with the Cretaceous strata of the Raven Pass anticline area and in contact with the Eocene Point of Rocks formation in the Shale Hills area, indicates that locally there was either a prolonged period of erosion prior to the deposition of the McDonald and Twisselmann and subsequent to the deposition of older Tertiary sediments, or, that the McDonald and Twisselmann were deposited under transgressive conditions. Inasmuch as the shale sequence on the northeast flank of the McDonald anticline in secs. 5, 8, and 9, T. 27 S., R. 18 E., is continuous from the Carneros contact through the Media, Gould-Devilwater, and McDonald without any evidence of unconformity, the conclusion is that the McDonald shale is merely a highly transgressive member. There is no hiatus, therefore, between the Temblor and the Monterey or within the Monterey itself.

Gould-Devilwater Shale Member. The Gould shale[11] and Devilwater[12] silt members of the Monterey are differentiated elsewhere in the San Joaquin Valley region on the basis of faunal evidence. However, these two units could not be separated by this same criterion in the area covered by this report. For this reason, a composite name, Gould-Devilwater shale, is used. An estimated maximum thickness of 1500 feet of this unit overlies the "Button bed" sandstone with apparent conformity.

In general two distinct types of lithology are present within the Gould-Devilwater sequence south of Bitterwater Creek. Hard silicified, locally cherty and resistant, platy, tan shale, 650 feet thick, with prominent topographic expression occurs in the lower part of the unit immediately overlying the "Button bed". The upper part of the unit varies in lithology. From the top downward it consists of the following:

Foraminiferal, *Valvulineria californica*, silty shale	100 feet
Siltstone or fine sandstone, bentonitic (?)	100 feet
Barren, chocolate-brown to lavender-gray silty clay shale and siltstone with thin intercalations of rusty-brown limestone	350 feet
Foraminiferal, *Valvulineria californica*, platy tan shale with oval, shaly limestone concretions	100 feet
	(all thicknesses estimated)

An intermediate thickness of unexposed rock in the middle of the section is probably very small, probably not more than 200 feet.

North of Bitterwater Creek, the distinction between these two types of lithology is difficult to make. For the most part, the section consists of soft and platy, gray silty shale. Occasional beds of hard, white porcelaneous shale and a few buff-colored limestone beds are intercalated. The total Gould-Devilwater section here averages some 800 feet in thickness, and is lithologically similar to shales found in the overlying McDonald.

Portions of the contact between the "Button bed" sandstone and the Gould-Devilwater shale appear to be gradational in the Cedar Canyon section. Foraminifera with affinities to the fauna of the type Gould occur in a transitional sequence at the top of the "Button bed" sandstone and at the base of the overlying hard platy shale of the Gould-Devilwater. No foraminifers of diagnostic value were found for approximately 650 feet stratigraphically above this transitional sequence. The 650 feet of hard platy shale could possibly be considered as Gould. Lithologically, however, it is difficult to distinguish it from the shales stratigraphically higher.

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[10] Bramlette, M. N., The Monterey formation of California and the origin of its siliceous rocks: U. S. Geological Survey Prof. Paper no. 212, pp. 3, 1946.

[11] Barbat, W. E., Age of the producing horizon at Kettleman Hills, California: Am. Assoc. Petroleum Geologists Bull. vol. 16, no. 6, pp. 611-612, 1932.

[12] Bailey, W. C., Wasco oil field: Div. Oil and Gas, Summary of Operations, vol. 24, no. 3, p. 7, 1939.

Despite the fact that the foraminifers at the base of the lower hard platy shale are similar to those in the "Button bed" sandstone, the general continuity in lithology from this lower shale to the upper part of the Gould-Devilwater, and also, the siliceous character of the lower shale require that it be recognized as a part of the Monterey rather than the Temblor formation.

North of Bitterwater Creek through secs. 5, 8, 9, and 16, T. 27 S., R. 18 E., the major part of the shale unit mapped as Gould-Devilwater is characterized by a flood of *Valvulineria californica.* This fauna also is present in some of the shales outcropping along the axial trace of the Cedar Canyon syncline.

Twisselmann Sandstone Member. The name Twisselmann is applied in this report to the prominent sandstone member of the Monterey formation in the Bitterwater Creek area. The type locality of this member is in the vicinity of C. Twisselmann's deserted ranch buildings located in the northwest corner of the northeast quarter of sec. 14, T. 27 S., R. 18 E. Specifically, typical outcrops of the sandstone are exposed in the northern portion of sec. 14, the southwestern portion of sec. 11, and the northeastern portion of sec. 10, T. 27 S., R. 18 E. The Twisselmann has a maximum thickness of 2200 feet in its type area, where it unconformably overlies the Cretaceous and is overlain conformably by the McDonald shale. The principal outcrops of the Twisselmann are along the northeast flank of the Raven Pass anticline; however, other outcrops are present at several localities in the area. The areal extent of the unit and the variation in its thickness from the maximum exposed at the type locality are clearly shown in plate 1.

The immediate area surrounding these outcrops is characterized by many structural as well as stratigraphic complexities. Much difficulty was experienced in placing the stratigraphic position of the unit accurately in relation to the Gould-Devilwater shale and to the McDonald shale. Previous published reports on the area by Arnold and Johnson [13] and English,[14] show the unit as the Vaqueros sandstone. However, foraminiferal evidence obtained during the present survey indicates that the unit is considerably higher in the stratigraphic column.

Microfossil samples collected from a shale bed [15] in the upper part of the Twisselmann contain a faunal assemblage almost identical with that collected from the McDonald along the Miocene-Cretaceous contact on the southwest flank of the Raven Pass anticline. The fauna in these samples indicates an early Mohnian age for both the McDonald and the upper part of the Twisselmann. Thus, at least a portion of the Twisselmann is equivalent to part of the McDonald. This is substantiated in the area south of Bitterwater Creek where the Twisselmann is found outcropping within the lower part of the McDonald. Nevertheless, in the lower part of the Twisselmann sandstone a megafossil assemblage was found (L. S. J. U. Loc. No. 2850), which is almost identical with that found in the Relizian "Button bed" sandstone (L. S. J. U. Loc. Nos. 2844-2847).

If the Twisselmann assemblage can be considered sufficiently diagnostic, the lower part of the Twisselmann in its type locality may be at least Luisian and correlative with a portion of the Gould-Devilwater shale. The evidence indicates, that in its type locality, the Twisselmann represents a rapid change in facies within the Monterey formation and corresponds in part to the Gould-Devilwater and the McDonald shale members.

The McDonald shale present through secs. 4, 5, 8, 9, and 10, T. 27 S., R. 18 E., contains varying amounts of fine- to coarse-grained sandstone. Therefore, at least a portion of the sandstone of the Twisselmann on the east side of the Raven Pass anticline is equivalent to the McDonald shale on the west side. The general thinning of the Twisselmann to the northwest of its type locality corresponds to the northwestward decrease in the amount of sandstone present in the McDonald shale exposed along the axial trace of the Third syncline (fig. 2) through secs. 5, 8, 9, and 10, T. 27 S., R. 18 E. Paralleling the northwestward thinning of the Twisselmann sandstone is the thickening of the upper shale bed within the Twisselmann from 30 feet in sec. 11, T. 27 S., R. 18 E., to approximately 175 feet in sec. 32, T. 26 S., R. 18 E.

The combined maximum thickness of the Twisselmann and McDonald exposed on the west flank of the Second syncline in sec. 11, T. 27 S., R. 18 E., is about 2800 feet. On the east flank of the Second anticline in sec. 12, T. 27 S., R. 19 E., this thickness decreases to about 1800 feet of which approximately a 200-foot thickness is the Twisselmann. It is evident then that the Twisselmann sandstone either changes laterally into the McDonald shale or is transgressively overlapped by the McDonald (pl. 2, E-E′). In the First anticline, the absence of the Twisselmann between the surface outcrops of the Point of Rocks sandstone and the McDonald shale points to its wedging out approximately under the First syncline. From its outcrop in sec. 7, T. 27 S., R. 19 E., the subsurface edge of the Twisselmann probably parallels the northwestward extension of the First anticline, and then passes into Antelope Valley east of its outcrop in sec. 27, T. 26 S., R. 18 E. The distribution of the Twisselmann in Antelope Valley is uncertain, but it may be identified with Miocene sands below the McDonald which have been logged in wells as "Kettleman," "Miocene," and "Oligocene" sandstone.

Lithologically, the Twisselmann is a silty and fine- to medium-grained sandstone; the greater part of the unit is fine-grained in texture. Grains are sub-angular to subrounded and consist of quartz, weathered feldspar, occasional muscovite, and a few dark chert-like particles. The sandstone is generally friable with little or no cementing material. Locally, the sandstone is well cemented with calcite and forms prominent outcrops. The sand grains are usually coarse in outcrops containing a large amount of calcareous cement. The Twisselmann varies in color

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[13] Arnold, Ralph, and Johnson, Harry R., Preliminary report on the McKitterick-Sunset oil region, Kern and San Luis Obispo Counties, California: U. S. Geol. Survey Bull. 406, pp. 11-225, 1910.

[14] English, Walter A., Geology and petroleum resources of northwestern Kern County, California: U. S. Geol. Survey Bull. 721, pp. 5-226, 1921.

[15] Cushman, Joseph A., and Goudkoff, Paul P., A new species of *Pulvinulinella* from the California Miocene: Cushman Lab. Foram. Research Contr., vol. 14, no. 1, pp. 1-2, 1938.

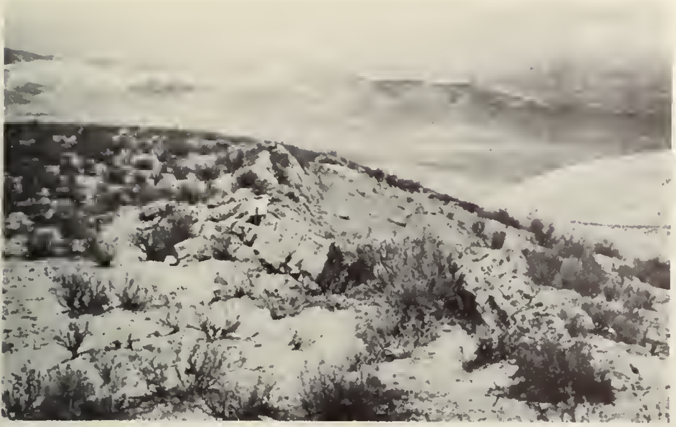


Fig. 9. Limestone bed in the lower part of the McDonald shale member of the Monterey southeast of Bitterwater Creek.

from an off-white to buff yellow. There is little evidence of bedding.

The contact between the Twisselmann and the Cretaceous is marked locally by a discontinuous, massive, 30 to 50 foot thick bioclastic reef which forms the base of the Twisselmann. Inasmuch as the Twisselmann is generally friable with few prominent outcrops, it is difficult to accurately place the Cretaceous-Twisselmann contact where the reef is absent. This reef is soft, rather friable, and is composed of almost pure organic material consisting of shell fragments of unidentifiable large and small pectens and oysters. The remainder of the reef consists of rounded quartz grains, weathered feldspar, and pebbles of black chert; numerous fragments of Cretaceous yellow-brown sandstone containing holes bored by mollusks occur directly at the base. The only fossils identified from this reef were specimens of *Pecten (Aequipecten) andersoni* Arnold. This same fossil appears abundantly in the Twisselmann in the east-central part of sec. 12, T. 27 S., R. 18 E., and in sec. 7, T. 27 S., R. 19 E., near the Shell Oil Company's well, Utting No. 3.

A continuous band of porcelaneous shale ranging in thickness from 30 to 175 feet is characteristically present in the upper portion of the Twisselmann as exposed on the northeast flank of the Raven Pass anticline. Locally, through secs. 11 and 14, T. 27 S., R. 18 E., two shale bands are present. The upper band is the continuous unit and gradually increases in thickness to the northwest until it attains a thickness of 175 feet in sec. 32, T. 26 S., R. 18 E. The lower shale band extends from sec. 14 about 2500 feet northwestward into sec. 11 where it disappears, probably due to a lateral change into sandstone. These two shale bands are referred to as the upper and lower shale marker beds respectively.

McDonald Shale Member. The McDonald shale member of the Monterey is present in the Bitterwater Creek area with a thickness of 1200 to 3000 feet. For the most part the unit consists of light colored siliceous shales interbedded with variable amounts of sandstone and some buff and rusty-brown colored limestone.

To the south of Bitterwater Creek, over 1900 feet of the McDonald overlies the Gould-Devilwater shale with apparent conformity. The highest Gould-Devilwater shale is soft and silty, whereas the basal 125 feet of the McDonald consists of splintery, diatomaceous shale which is distinguished by pencil-shaped rectangular jointing. This basal shale is overlain by approximately 775 feet of gray diatomaceous and porcelaneous shale which fractures into block-shaped pieces. Beds of dense, finely laminated, rusty-brown limestone, 1 foot to 2 feet thick, outcrop prominently in this portion of the shale at stratigraphic intervals of 5 to 10 feet, and extend along the strike for several hundreds of feet. Although the adjacent shale is barren, certain of the limestone beds contain foraminifers in abundance. The tests are often identifiable and indicate an early Mohnian age for this 900-foot shale sequence.

In the middle of the McDonald section south of Bitterwater Creek are 380 feet of friable, fine-grained quartzose sandstone with occasional streaks of silty shale. This sandstone, although entirely within the McDonald, is considered to be the Twisselmann sandstone.

The portion of the McDonald overlying the Twisselmann south of Bitterwater Creek consists of 600+ feet of hard, gray to light-brown, siliceous and porcelaneous shale of uniform character. Buff-yellow and rusty-brown limestone concretions 2 to 6 feet in their maximum diameter, and elongated parallel to the bedding, occur at stratigraphic intervals of 10 to 100 feet. Laterally the concretions are separated from one another by distances of 15 feet or more. Like the limestone beds in the lower part of the McDonald, these concretions occasionally contain microfossils. Throughout the entire area outcrops of the stratigraphically highest McDonald exposed are characterized by the occurrence of these concretions. It is thought that the presence of limestone beds in the lower part of the McDonald and of limestone concretions in the upper part furnishes a means of determining the stratigraphic sequence. On this basis, the portion of the McDonald which underlies the Twisselmann south of Bitterwater Creek is not present north of Bitterwater Creek in the Shale Hills outcrop area of the McDonald.

The lithology of the McDonald along the southwest flank of the Raven Pass anticline is different from that either in the Shale Hills or that to the south of Bitterwater Creek. The shale, though siliceous, is silty and contains numerous beds of sandstone up to 10 feet thick. The sandstone beds range from an off-white, friable, well-sorted, fine-grained sandstone to a yellow, calcareous, coarse to gritty sandstone. In the portion of the McDonald interbedded with sandstone there are no limestone beds or concretions of the type found south of Bitterwater Creek and in the Shale Hills section. Instead, the limestone which is present occurs as calcareous cement in the sandstone beds.

The silty shale with interbedded sandstone is the dominant lithologic feature of the McDonald through sec. 9, T. 27 S., R. 18 E. Northwest of sec. 9 along the strike the shale becomes more porcelaneous and less silty and buff-colored limestone beds appear. Throughout the section where the sandstone beds are common, prominent sandstone dikes are often present. These dikes probably derived material from the sandstone beds within the McDonald and not from older formations. South of Bitterwater Creek, the dikes in the upper part of the McDonald shale pass from the sandstone of the underlying Twisselmann into the McDonald.

The most common type of shale in the McDonald in the Shale Hills is a white, hard, porcelaneous shale with

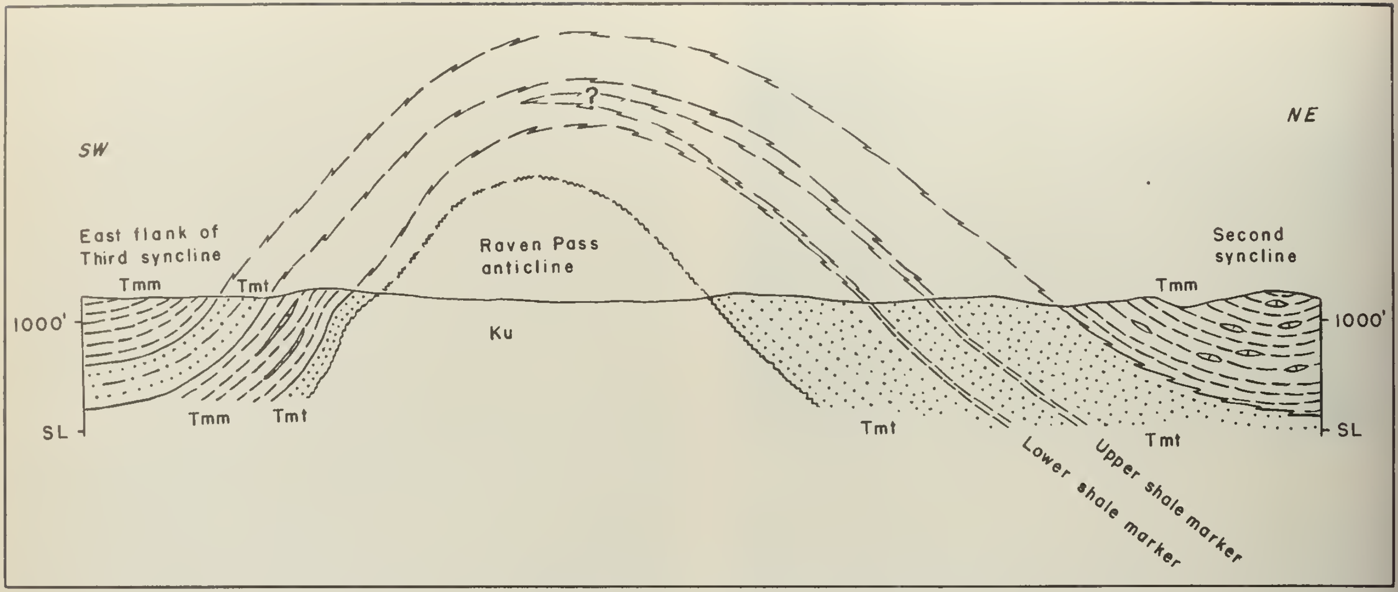


FIG. 10. Relationship between the McDonald shale and the Twisselmann sandstone. (A portion of cross-section E-E'.)

blocky, conchoidal fracture. Interbedded with the porcelaneous shale are beds of soft, fissile siliceous shale which are buff-white to white on weathered surfaces and light lavender on fresh surfaces. Well cuttings of the shale exhibit either a chocolate-brown or a dark-blue color. Thin beds of this shale break into jagged, pencil-like laths several inches long. Limestone concretions, occasionally fossiliferous, are common, as in the corresponding section south of Bitterwater Creek.

Although on the whole the McDonald is unfossiliferous, in all of the outcrop areas it was possible to find a few samples rich in microfossils. These samples were obtained principally from the limestone beds and concretions; in a few instances microfossils were found in the shales. Fish scales were noted quite frequently and bone fragments of vertebrates are common as float, particularly in the Shale Hills. Most of these are vertebrae of the great sulphur bottom whale. In several instances bone material was found in the center of the limestone concretions, which may possibly be a clue to the origin of these concretions.

Pliocene-Pleistocene

Tulare Formation

The Pliocene and possibly the Pleistocene are represented in the area by the Tulare formation which rests unconformably on the older sediments. The Tulare consists of approximately 90 percent siliceous shale fragments. The remainder consists of boulders and cobbles of limestone, schist, gneiss, chert, and granitic rocks. No stratification is apparent and consolidation is poor.

To the west of the area studied, the Tulare is present in canyons bordering the San Andreas fault and consists

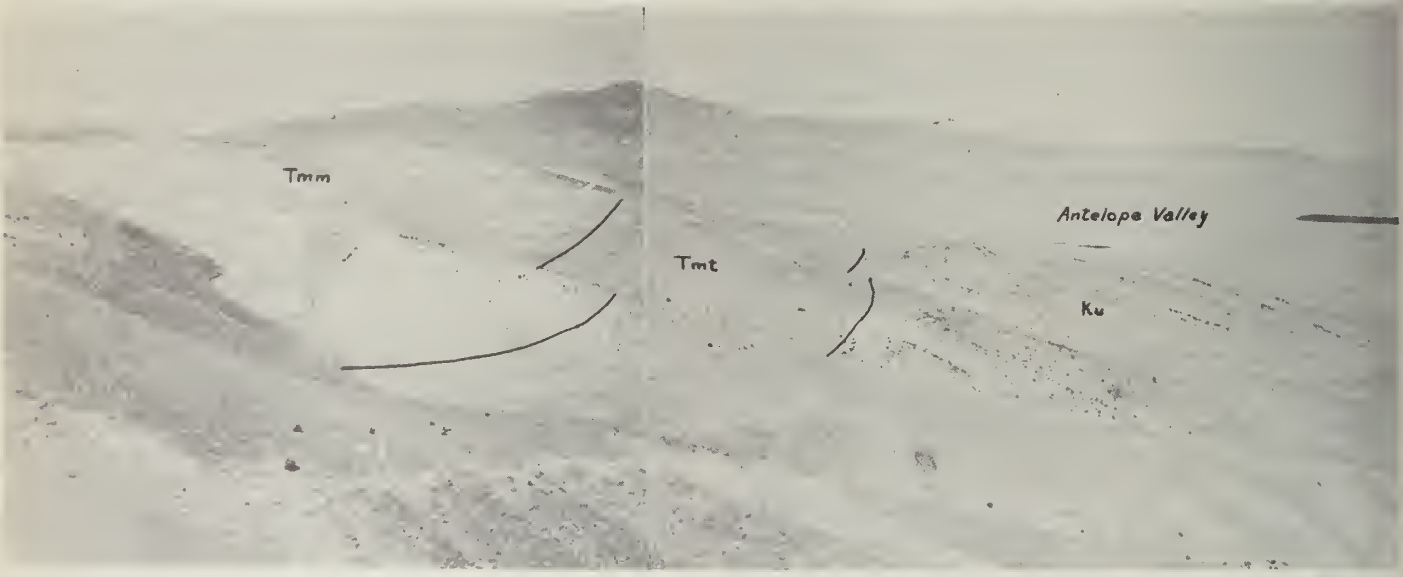
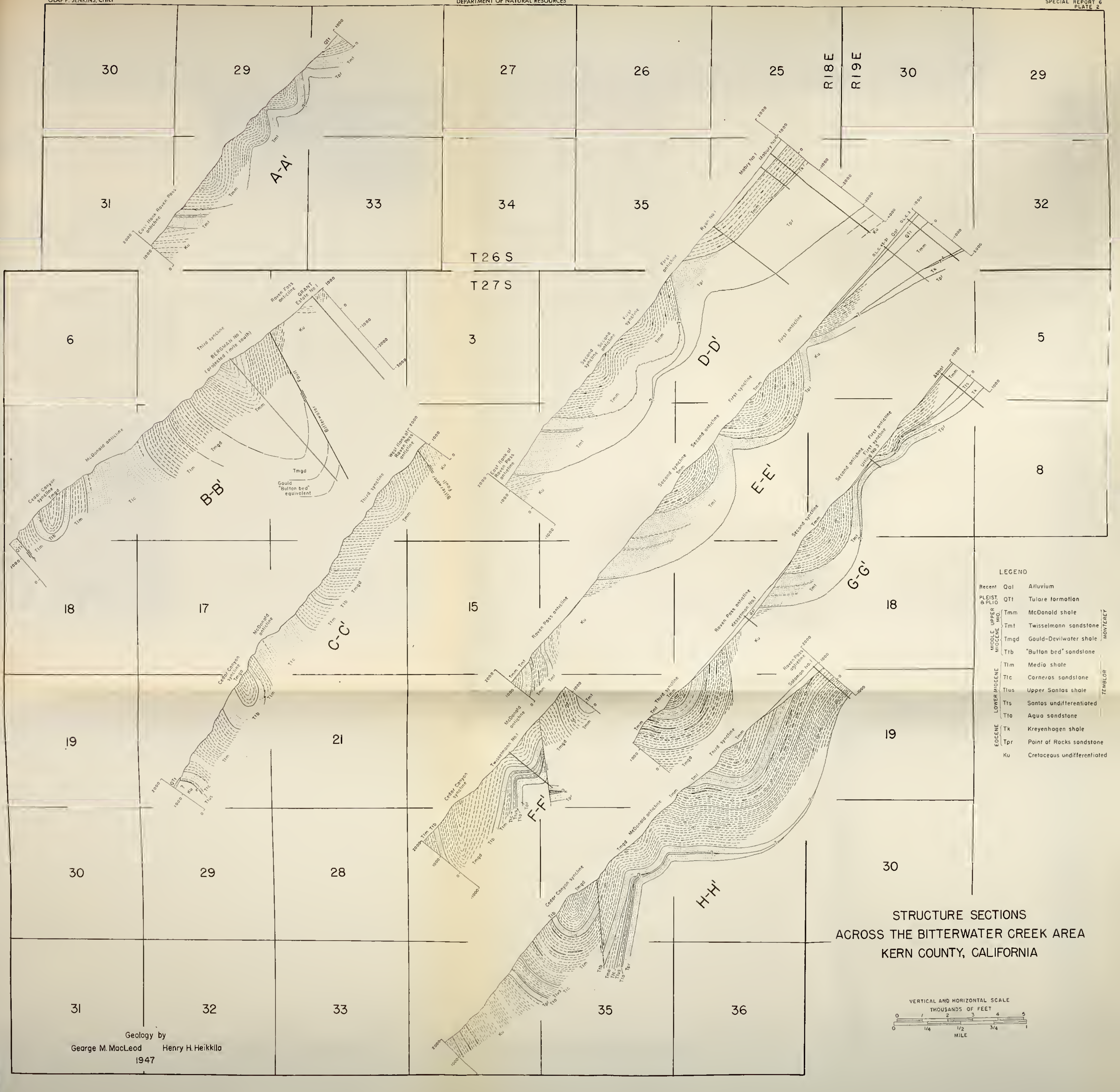


FIG. 11. Miocene overlap of the Cretaceous in Shale Hills, sec. 28, T. 26 S., R. 18 E. The Cretaceous is on the right, and appears as dark-colored beds dipping into Antelope Valley. In the center is the Twisselmann sandstone; on the left are gently dipping beds of the McDonald shale. The car tracks in the center foreground indicate the scale.

DIVISION OF MINES
OLAF P. JENKINS, CHIEF

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

SPECIAL REPORT 6
PLATE 2



STRUCTURE SECTIONS ACROSS THE BITTERWATER CREEK AREA KERN COUNTY, CALIFORNIA

Geology by
George M. MacLeod Henry H. Heikkila
1947

of sandstone, siltstone, and mudstone with well-developed bedding. A few shale fragments were found, but no conspicuous fragmental material of metamorphic and igneous rocks was found.

As no fossils were found, the correlation of these sediments with the Tulare in the Kettleman Hills area is based entirely on lithologic similarity and stratigraphic position.

Pleistocene(?)-Recent

Terrace Gravel and Alluvium

On the northeast side of Cedar Canyon, and for a short extent along Bitterwater Creek northwestward from the mouth of Cedar Canyon, isolated patches of Pleistocene(?)-Recent terrace gravels occur on the lower slopes of ridges.

STRUCTURE

The principal structural features in the Bitterwater Creek area are a series of northwest-trending folds bordering the western edge of the San Joaquin Valley. The folds are slightly oblique to the trend of the Temblor Range and pass southeastward from the foothills into the Antelope and San Joaquin Valleys. The folding in many places is complicated by faulting and overturning. Lower Miocene sediments are overturned through most of their outcrop area.

In the Shale Hills there is a series of tightly folded, roughly parallel, minor flexures. The axes of the individual folds curve considerably, and there is much squeezing of the strata in localities where the axes converge. These minor folds are not everywhere distinct and, hence, are not always easy to follow in the field. Normal folding is difficult to distinguish from local overturning, especially in the McDonald shale, because of its apparent ease of deformation. This is particularly true in secs. 27, 28, and 34, T. 26 S., R. 18 E.

In the portion of the Shale Hills northwest of Packwood Creek, there are numerous small folds complicated by the convergence of structural axes and local transverse faults. Southeast of Packwood Creek the structure consists of four easily recognizable folds, is less complex, and is easier to map. An interesting feature in sec. 1, T. 27 S., R. 18 E., is the prominent synclinal valley formed by the First syncline (fig. 2). The adjacent flexures to the southwest, the Second anticline and the Second syncline are clearly visible in secs. 11 and 12, but are obscure in sec. 2.

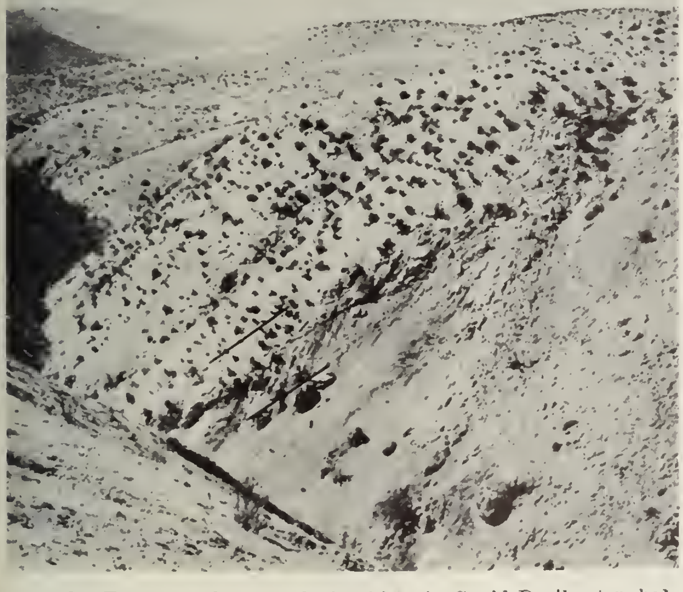


FIG. 12. Exposure of reverse fault within the Gould-Devilwater shale in sec. 26, T. 27 S., R. 18 E. The lack of drag features on both sides of the fault is apparent. The hammer and cap indicate the scale.

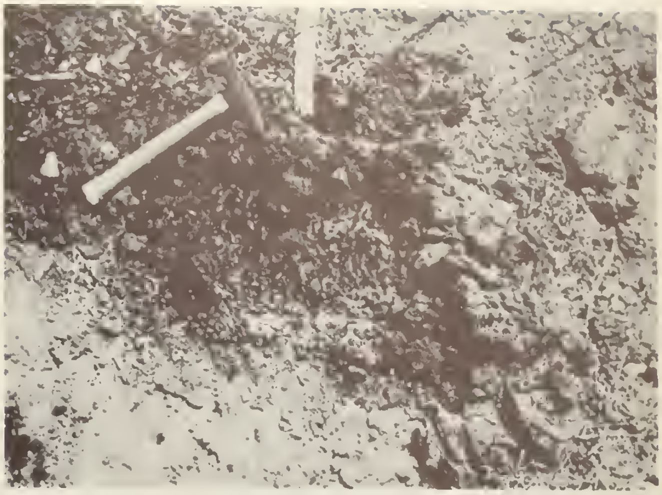


FIG. 13. Oil seep near the Abbott No. 1 well in sec. 7, T. 27 S., R. 19 E.

Immediately to the southwest of the Shale Hills structures, along the axial trace of the Raven Pass anticline, is an extensive outcrop of Cretaceous rocks, which forms a major structural high within the area. The Cretaceous outcrop is nearly a mile wide across the trend of the anticline and extends from Raven Pass, approximately 2 miles northwest of the area, to Bitterwater Creek where the anticline plunges southeast beneath the alluvium of the valley. There is little evidence from the strike and dip of bedding in the Cretaceous that the structure of the Cretaceous sediments conforms at all to that of the overlying Miocene. The axial trace of the Raven Pass anticline, as shown on the geologic map, holds true for the flanking Miocene sediments rather than for the Cretaceous itself. Post-Miocene folding merely has superimposed a regional structure upon the previously deformed Cretaceous sediments.

There is a normal sedimentary contact between the Cretaceous and the Miocene on the northeast limb of the Raven Pass anticline, but, on the southwest limb through secs. 4, 5, 9, and 10, T. 27 S., R. 18 E., the contact between the Cretaceous and the McDonald shale is mapped as the Bitterwater fault. In sec. 10 the fault swings to the south and southwest until it terminates in the southwest quarter of sec. 15. Evidence for the fault contact between the Miocene McDonald and the Cretaceous is found in the presence of a conspicuous amount of gypsum and caliche at several localities along the contact, and by the presence of very highly brecciated Cretaceous material. Perhaps the most convincing evidence is the presence of some 5900 feet of Miocene sediments in the Bergman No. 1 well in the northwest quarter of sec. 5, T. 27 S., R. 18 E., approximately one third of a mile from the Cretaceous-Miocene contact (pl. 2, E-E′).

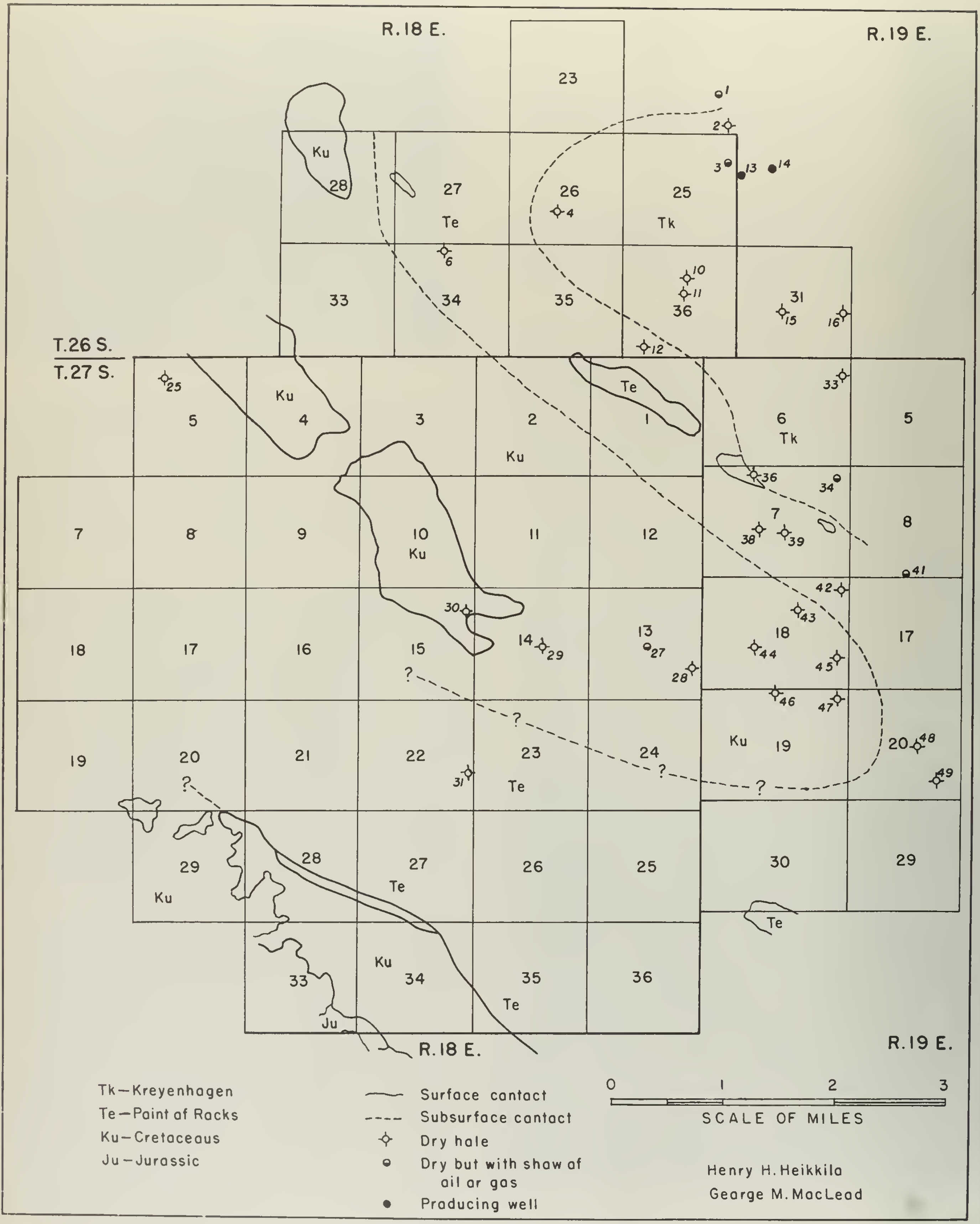


FIG. 14. Present distribution of pre-Temblor sediments.

Evidence for the swing of the fault to the south and southwest in sec. 10 is conclusive. In secs. 10 and 15 the beds of the McDonald terminate abruptly against the Cretaceous and the axis of the Third syncline has been displaced about 1 mile to the south. In addition, drag folds are present in the McDonald on adjacent sides of the southwesterly extension of the fault.

Movement in secs. 10 and 15 has been primarily horizontal whereas that along the McDonald-Cretaceous contact has been normal, nearly vertical, and substantially along the plane of the bedding. The sinuous course of the fault, the drag folds in the McDonald in sec. 15, and the large horizonal displacement of the axial trace of the Third syncline (fig. 2) all point to the possibility that the Bitterwater fault may be a thrust. Nevertheless, the evidence from the Bergman well makes the angle of the fault so steep that a thrust seems unreasonable (pl. 2, B-B′).

In previous work by English [16] the contact between the Twisselmann and the Cretaceous in sec. 15, on the southwest flank of the Raven Pass anticline was mapped as a fault contact. However, during the present survey no evidence was found to substantiate this and it is thought that the contact is a normal sedimentary one.

Another area in which the Cretaceous was mapped previously [17] in fault contact with the Miocene is in secs. 21 and 28, T. 26 S., R. 18 E. A normal depositional contact with an angular unconformity between the Miocene and Cretaceous, however, is indicated. The Cretaceous is overlain unconformably by the Miocene Twisselmann sandstone which in turn is overlain conformably by the McDonald shale. The pattern of the structure as well as the manner in which the Miocene sediments flank the Cretaceous support a sedimentary contact. Further evidence of a sedimentary contact is furnished by the presence of a small amount of glauconitic sand at the Cretaceous-Miocene contact.

The McDonald anticline is the second largest structural feature in the Bitterwater Creek area, and can be traced from the edge of the San Joaquin Valley, secs. 31 and 32, T. 27 S., R. 18 E., northwestward across the entire area. The axial trace of the McDonald anticline, and that of the Cedar Canyon syncline to the southwest are displaced by complicated faulting in secs. 23 and 26, T. 27 S., R. 18 E. In addition, the presence of several smaller anticlinal and synclinal folds adds to the structural complexity. Northwest of Bitterwater Creek massive outcrops of the Carneros sandstone are exposed along the axial trace of the McDonald anticline. Through secs. 16, 17, and 21, T. 27 S., R. 18 E., the anticline is overturned and precise mapping of the axial trace is made difficult by the overturning as well as by the lack of marker horizons in the Carneros.

The portion of the area southwest of the McDonald anticline is marked by conspicuous overturning accompanied by reverse faulting along the bedding planes in the Tertiary and Cretaceous strata. The rocks exposed on both flanks of the Cedar Canyon syncline are overturned through the entire area west and northwest of the north-trending reverse fault in sec. 26, T. 27 S., R. 18 E.; south of the fault the syncline is no longer overturned. Through the major portion of secs. 26 and 23 the fault is mapped as a thrust dipping approximately 55° to the west. In sec. 23 it apparently truncates a minor northwest-plunging anticline. This anticline continues to the northwest where it joins the McDonald anticline in the central portion of sec. 22. It is apparent that there is the possibility of structural closure up-dip against the fault. This was the geologic basis for the well drilled in the southeast quarter of sec. 22. The well encountered the fault but, nevertheless, was dry.

Table 3. Identification of wells shown on plate 1 and figure 14.

Legend no.	Well name	Operator	Location
1	No. 24-1	Mace A. Cox	Sec. 24, T. 26 S., R. 18 E.
2	Mabury No. 2	Continental Oil Co.	Sec. 24, T. 26 S., R. 18 E.
3	Mabury No. 1	Continental Oil Co.	Sec. 25, T. 26 S., R. 18 E.
4	Mabury No. 3	Continental Oil Co.	Sec. 26, T. 26 S., R. 18 E.
5	Well No. 1	Gerrard Oil Co.	Sec. 28, T. 26 S., R. 18 E.
6	Bramlette No. 1	Universal Consolidated	Sec. 34, T. 26 S., R. 18 E.
7	No. 1	Ash Oil Syndicate	Sec. 35, T. 26 S., R. 18 E.
8	Berry No. 2	Robert Berry	Sec. 35, T. 26 S., R. 18 E.
9	Berry No. 3	William Gilbert	Sec. 35, T. 26 S., R. 18 E.
10	Mabury No. 4	Independent Exploration Co.	Sec. 36, T. 26 S., R. 18 E.
11	Mabry No. 1	Hancock Oil Co.	Sec. 36, T. 26 S., R. 18 E.
12	Ryan No. 1	Superior Oil Co.	Sec. 36, T. 26 S., R. 18 E.
13	Occidental No. 8NW30	Etienne Lang	Sec. 30, T. 26 S., R. 19 E.
14	Occidental No. 6NW30	Etienne Lang	Sec. 30, T. 26 S., R. 19 E.
15	O.L.C. 45-31	Independent Exploration Co.	Sec. 31, T. 26 S., R. 19 E.
16	O.L.C. 3	Superior Oil Co.	Sec. 31, T. 26 S., R. 19 E.
17	No. 1	Day Oil Co.	Sec. 1, T. 27 S., R. 18 E.
18	No. 4	Rio California Petroleum Co.	Sec. 2, T. 27 S., R. 18 E.
19	B. Carney No. 1	Rio California Petroleum Co.	Sec. 2, T. 27 S., R. 18 E.
20	No. 1 (New)	California American Petroleum Corp. (formerly E. M. Byers)	Sec. 2, T. 27 S., R. 18 E.
21	No. 1	California American Petroleum Corp. (formerly E. M. Byers)	Sec. 2, T. 27 S., R. 18 E.
22	No. 1	Big Eight Oil Co.	Sec. 2, T. 27 S., R. 18 E.
23	No. 1	C. F. Akers	Sec. 3, T. 27 S., R. 18 E.
24	Grant Estate No. 1	The Texas Co.	Sec. 4, T. 27 S., R. 18 E.
25	Bergman No. 1	Trical Oil Co.	Sec. 5, T. 27 S., R. 18 E.
26	?	Unknown	Sec. 12, T. 27 S., R. 18 E.
27	Kesselman No. 1	Oildale	Sec. 13, T. 27 S., R. 18 E.
28	Solomon No. 1	The Texas Co.	Sec. 13, T. 27 S., R. 18 E.
29		Doyle Petroleum Co.	Sec. 14, T. 27 S., R. 18 E.
30	Twisselmann No. 1		Sec. 15, T. 27 S., R. 18 E.
31	Twisselmann No. 1	Signal-Honolulu Cos.	Sec. 22, T. 27 S., R. 18 E.
32	?	Unknown	Sec. 25, T. 27 S., R. 18 E.
33	?	Superior Oil Co.	Sec. 6, T. 27 S., R. 19 E.
34	No. 1	F. E. Abbot	Sec. 7, T. 27 S., R. 19 E.
35	?	Unknown	Sec. 7, T. 27 S., R. 19 E.
36	Utting No. 1	Rio Grande Oil Co.	Sec. 7, T. 27 S., R. 19 E.
37	?	Unknown	Sec. 7, T. 27 S., R. 19 E.
38	Utting No. 3	Shell Oil Co.	Sec. 7, T. 27 S., R. 19 E.
39	Utting No. 1	Shell Oil Co. (core hole)	Sec. 7, T. 27 S., R. 19 E.
40	?	Unknown	Sec. 7, T. 27 S., R. 19 E.
41	Mercantile No. 1	Standard Oil Co.	Sec. 8, T. 27 S., R. 19 E.
42	Mountford No. 1	Miller and York	Sec. 18, T. 27 S., R. 19 E.
43	Mountford No. 1	H. S. Mountford	Sec. 18, T. 27 S., R. 19 E.
44	Monford No. 1	Monford	Sec. 18, T. 27 S., R. 19 E.
45	Mountford No. 2	B. C. Morrison	Sec. 18, T. 27 S., R. 19 E.
46	Mountford No. 1	The Texas Co.	Sec. 19, T. 27 S., R. 19 E.
47	McClellan No. 1	The Texas Co. (core hole)	Sec. 19, T. 27 S., R. 19 E.
48	Grabe No. 1	The Texas Co.	Sec. 20, T. 27 S., R. 19 E.
49	U.S.G. 66-20	British American and Atlas Producing Cos.	Sec. 20, T. 27 S., R. 19 E.

In the northeastern portion of sec. 29, T. 27 S., R. 18 E., the Point of Rocks formation and the Agua sandstone are missing and the upper Santos shale is mapped in fault contact with the Cretaceous. Because a 600-foot thickness of the Point of Rocks formation is exposed only several hundred feet away on the east side of the mouth of Cedar Canyon, it must be assumed that the Point of Rocks and the Agua have been overridden by the incompetent Cretaceous sediments during the intense folding and overturning of the section. In secs. 19 and 20, T. 27 S., R. 18 E., the structural relationship between the Eocene

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[16] English, Walter A., Geology and petroleum resources of northwestern Kern County, California: U. S. Geol. Survey Bull. 721, pp. 5-226, 1921.

[17] Op. cit.

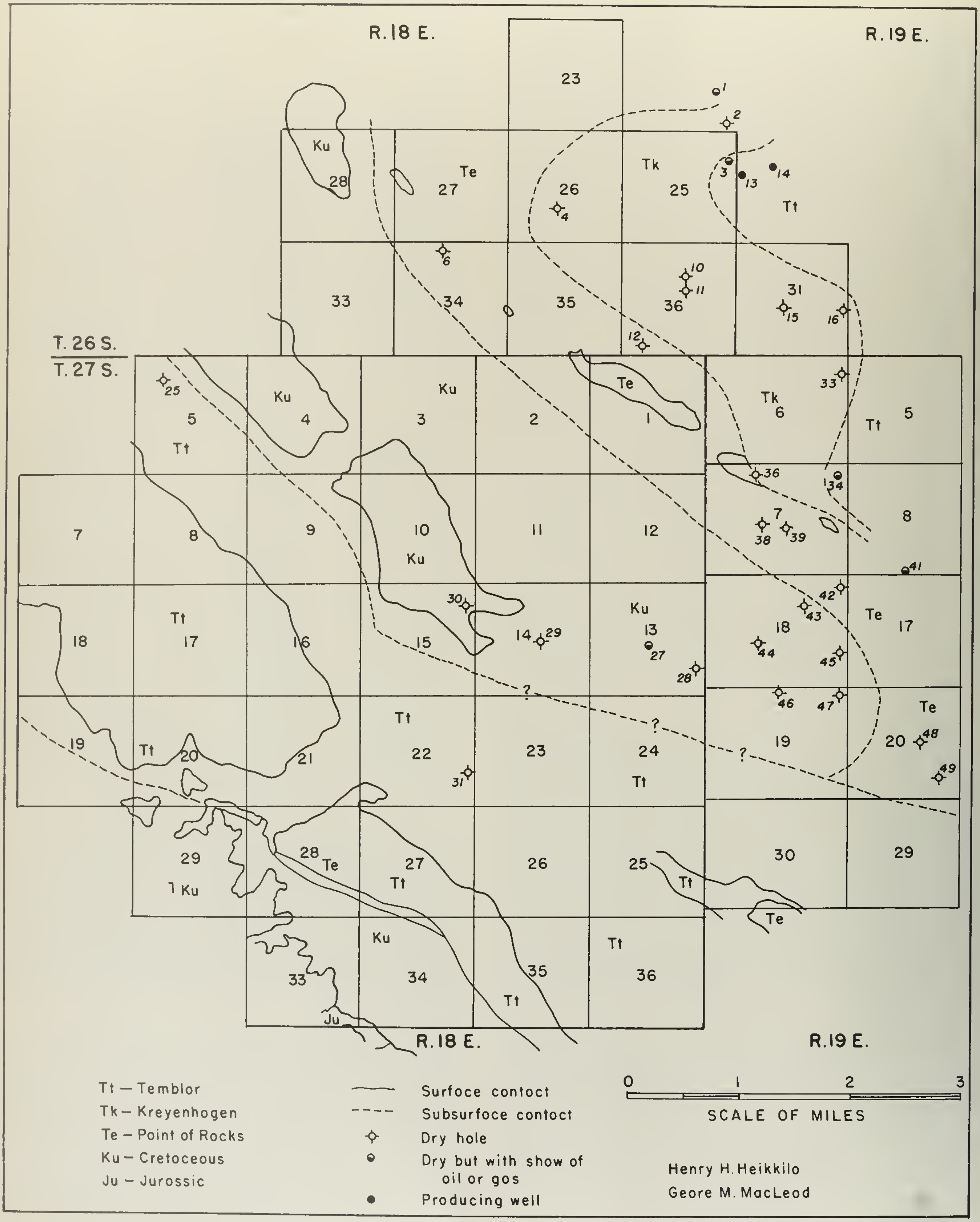

FIG. 15. Present distribution of pre-Monterey sediments.

and early Miocene sediments and the Cretaceous is obscured by the overlap of the Tulare.

The Miocene-Tulare contact in the west-central portion of sec. 18, T. 27 S., R. 18 E., is mapped as a fault contact. The fault is thought to be present in a well-developed tributary canyon running south into Bitterwater Creek. Miocene sediments are visible on the east wall of the canyon; the entire west wall consists of the debris characteristic of the Tulare formation. On the west side of the canyon near the north end of the fault, there is a good exposure of soft, yellow clay-like fault gouge.

ECONOMIC PROSPECTS

To facilitate the discussion of the economic prospects, two small scale maps have been constructed (figs. 14 and 15) to show the present areal distribution of the different sedimentary formations. These two maps show the positions of the pre-Temblor and pre-Monterey sediments. They are not paleogeologic maps as they do not necessarily show the position of the pre-Temblor or pre-Monterey sediments at the beginning of the deposition of the Temblor or of the Monterey. They show only conditions as they exist today and have been constructed by using information obtained from surface outcrops as well as available subsurface information from well logs. Surface outcrops are shown surrounded by solid lines; inferred subsurface occurrence is bounded by dashed lines. More or less arbitrary boundary restrictions were imposed for the area covered. Information from the Blackwell's Corner field has been included only to the extent necessary to show the relation of production to the truncated Temblor edge.

It is thought that the best opportunity for petroleum production in this area lies in the location of sedimentary wedge edges in structurally favorable areas. Such a condition is found in the Blackwell's Corner field where the Temblor is overlapped across the nose of a southeastward plunging anticline. The discovery of commercial production along the truncated edge of the Temblor in this field has led to hope for an extension of the productive edge in the area immediately to the northeast of the Shale Hills. Several dry holes have been drilled in an attempt to locate this edge in the area lying between Shale Hills and the Blackwell's Corner field. An examination of the small scale maps (figs. 14 and 15) will show that so far the wells have all been located to the southwest of the Temblor edge. The F. Abbot dry hole in the northeast corner of sec. 7, T. 27 S., R. 19 E., was the only location to find Temblor sediments. This well is reported to have cored Santos shale at the comparatively shallow depth of 755-1041 feet. The productive possibilities of the Temblor edge are emphasized by the fact that in 1947 there was an active oil seep at the F. Abbot location. In spite of the dry holes obtained to date there is still some prospect of obtaining production from the Temblor edge in the area immediately northeast of the Shale Hills.

The truncated edge of the Temblor as well as of the Eocene Point of Rocks is present under possibly favorable structural conditions along the flanks of the Raven Pass anticline south of Bitterwater Creek. In this portion of the area the Temblor edge is for the most part the edge of the transgressive "Button bed" sandstone. The outcrops in sec. 30, T. 27 S., R. 19 E., show the "Button bed" lying on the Point of Rocks. The pre-"Button bed" Temblor members have been truncated and overlapped by the "Button bed" so that their wedge edge positions lie to the southwest of the subsurface contact shown.

The chances of obtaining production along this edge as well as from that of the paralleling Eocene Point of Rocks edge is controlled by the positions of these two edges with respect to the axes of the Third syncline and the Raven Pass anticline. This information could be readily obtained by a series of comparatively shallow core holes.

The fact that the general plunge of the structures in the area is to the east and southeast makes sec. 15, T. 27 S., R. 18 E., of some interest as the Bitterwater fault crosses this section nearly normal to the strike, and hence, should also cut across the Temblor and Point of Rocks edges if they are present.

In secs. 18 and 20, T. 27 S., R. 19 E., where the unit Te is shown to cross the Raven Pass anticline, wells 42, 48, and 49, indicate that the Point of Rocks as a sandstone unit is absent, so that Eocene shale underlies the Monterey. Since the Point of Rocks definitely reappears as a surface outcrop in sec. 30, T. 27 S., R. 18 E., it is possible that the shale is a result of a local change in facies within the Eocene. For this reason the symbol Te has been used in spite of the fact that the stratigraphic unit so designated is the Eocene Point of Rocks over the balance of the area.

SUMMARY

The sandstone present along the axial trace of the First anticline in Shale Hills, previously considered to be the Vaqueros sandstone, is mapped as the Eocene Point of Rocks sandstone.

The large sandstone body present along the axial trace of the McDonald anticline through secs. 7, 8, 16, and 17, T. 27 S., R. 18 E., is recognized as the Carneros sandstone member of the Temblor formation. Its increase in thickness in this area from its exposures in the adjacent Cedar Canyon section is due primarily to a lateral change of the Media and upper Santos shales into sandstone and is related to a local thickening of the Temblor sediments.

A new unit, the Twisselmann sandstone, is recognized as a member of the Monterey formation in the Shale Hills. This new unit is considered in part Luisian and in part Mohnian.

The Miocene rocks on the southwest limb of the Raven Pass anticline are in fault contact with the Cretaceous. The Miocene-Cretaceous contacts in secs. 21 and 28, T. 26 S., R. 18 E., and in sec. 15, T. 27 S., R. 18 E., are considered depositional contacts and are not fault contacts as previously mapped.

The present distribution of sediments indicates that there are still untested areas where it may be possible to obtain production of oil and/or gas from the overlapped or truncated edges of the Temblor and possibly the Point of Rocks.

REGISTER OF FOSSIL LOCALITIES

L.S.J.U. Locality No. 2844
Packwood Quadrangle, grid coordinates: 938.36, 769.46; NW Sec. 27, T. 27 S., R. 18 E.
Bruclarkia oregonensis (Conrad)
Calyptraea filosa Gabb
Conus owenianus Anderson
Nuculana (Saccella) ochsneri (Anderson and Martin)
Pecten (Aequipecten) andersoni Arnold

L.S.J.U. Locality No. 2845
Packwood Quadrangle, grid coordinates: 937.70, 770.23; EC sec. 27, T. 27 S., R. 18 E.
Balanus ? sp.
Calyptraea filosa Gabb
Dosinia margaritana Wiedey
Macoma sp.
Nuculana (Saccella) ochsneri (Anderson and Martin)
Pecten (Aequipecten) andersoni Arnold

L.S.J.U. Locality No. 2846
Shale Point Quadrangle, grid coordinates: 937.7, 773.05; C sec. 25, T. 27 S., R. 18 E.
Calyptraea filosa Gabb
Dosinia margaritana Wiedey
Mytilus mathewsonii var. *expansus* Arnold
Nuculana (Saccella) ochsneri (Anderson and Martin)
Pecten (Aequipecten) andersoni Arnold
Pecten (Lyropecten) crassicardo (Conrad)

L.S.J.U. Locality No. 2847
Shale Point Quadrangle, grid coordinates: 937.15, 774.5; SW sec. 30, T. 27 S., R. 19 E.
Bruclarkia oregonensis (Conrad)
Linga (Here) richthofeni (Gabb)
Macoma sp.
Miltha sanctaecrucis Arnold
Natica (Neverita) cf. *N. andersoni* Clark
Nuculana (Saccella) ochsneri (Anderson and Martin)
Panope generosa (Gould)
Pecten (Aequipecten) andersoni Arnold
Solen sp.

L.S.J.U. Locality No. 2848
Packwood Quadrangle, grid coordinates: 940.80, 770.60; SW Sec. 14, T. 27 S., R. 18 E.
Baculites cf. *B. chicoensis* Trask

L.S.J.U. Locality No. 2849
Sawtooth Ridge Quadrangle, grid coordinates: 947.75, 768.1; NW sec. 28, T. 26 S., R. 18 E.
Baculites cf. *B. chicoensis* Trask
Euspira shumardiana (Gabb)
Fusinus sp.
Glycymeris sp.
Pinna ? sp.
Puzosia ? sp.
Trigonocallista nitida (Gabb)

L.S.J.U. Locality No. 2850
Packwood Quadrangle, grid coordinates: 943.35, 770.1; NE sec. 10, T. 27 S., R. 18 E.
Bruclarkia oregonensis (Conrad)
Ficus (Trophosycon) ocoyana (Conrad)
Macoma sp.
Pecten (Aequipecten) andersoni Arnold
Solen sp.
Spisula sp.
Turritella cf. *T. ocoyana* Conrad

L.S.J.U. Locality No. 2862
Packwood Quadrangle, grid coordinates: 937.85, 768.05; C sec. 28, T. 27 S., R. 18 E.
Pecten (Lyropecten) magnolia Conrad
Pecten (Lyropecten) perrini Arnold ?

ANNOTATED BIBLIOGRAPHY

Anderson, Frank M., A stratigraphic study in the Mount Diablo Range, California: California Acad. Sci. Proc., 3d ser., vol. 2, no. 2, pp. 155-248, 1905.

This is an early paper on stratigraphy in California in which the following terms are proposed: Kreyenhagen shales, Avenal sandstones, Domijean (sic) sands, Temblor beds including the "Button beds", Etchegoin beds including the Etchegoin sands and the San Joaquin clays, and the Tulare formation.

Anderson, Frank M., and Martin, Bruce, Neocene record in the Temblor Basin, California, and Neocene deposits of the San Juan District, San Luis Obispo County: California Acad. Sci. Proc., 4th ser., vol. 4, pp. 15-112, December, 1914.

The type locality of the Temblor formation is redefined as Carneras (Carneros) Springs (p. 39).

Arnold, Ralph, and Johnson, Harry R., Preliminary report on the McKittrick-Sunset oil region, Kern and San Luis Obispo Counties, California: U. S. Geol. Survey Bull. 406, pp. 37-39, 45-47, 58-59, 64, 75, 207, 1910.

A discussion is presented of the geology of the Temblor Range north of and in the McKittrick-Sunset area. A short description of the geology and paleontology of the "Vaqueros" and "Santa Margarita" formations in the vicinity of Bitterwater Creek is of interest. Geologic map.

Bailey, William C., Wasco oil field: California Oil Fields, vol. 24, no. 3, pp. 66-71, 1939.

As far as can be determined, this article contains the first published usage of the term Devilwater silt applied to the *Valvulineria californica* zone of the Monterey formation.

Barbat, W. F., Age of producing horizon at Kettleman Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 16, no. 6, pp. 611-612, 1932.

The term Gould shale is formally proposed for "220 to 230 feet of beds overlying the Button bed member of the Temblor formation and underlying the *Valvulineria californica* zone of the Monterey formation . . ."

Bramlette, M. N., The Monterey formation of California and the origin of its siliceous rocks: U. S. Geol. Survey Prof. Paper 212, 1946.

The ecologic conditions, and diagentic and metamorphic processes involved in the formation of the Monterey shales are discussed. A section on stratigraphy and correlation is presented in which it is suggested that the name Monterey be applied to upper middle and upper Miocene siliceous rocks which have been given local stratigraphic names.

Clark, L. M., and Clark, Alex, The Vaqueros in the Temblor Range (abst.): Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 1, p. 137, 1935.

Notice is given of the occurrence of "Vaqueros" fossils from Carneros Creek to Cedar Canyon and their bearing upon the Temblor-Vaqueros problem.

Cunningham, George M., and Barbat, William F., Age of producing horizon at Kettleman Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 16, no. 4, pp. 417-421, April 1932.

Credit is given to this article for the first publication of the terms Gould shale, Media shale, and Carneros sandstone. (See reference to May and Gilboe.)

Curran, John F., Eocene stratigraphy of the Chico Martinez Creek area, Kern County, California: Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 10, pp. 1361-1386, 1943.

This article covers the stratigraphy and paleontology of the Eocene strata immediately subjacent to the Zemorrian stage in the Chico Martinez Creek area.

Cushman, Joseph A., and Goudkoff, Paul P., A new species of *Pulvinulinella* from the California Miocene: Cushman Lab. Form. Research Contr., vol. 14, pt. 1, pp. 1-2, 1938.

This is considered to be the first published usage of the name McDonald for lower Mohnian shale developed along the west side of the San Joaquin Valley. The holotype of *Pulvinulinella gyroidinaformis* was obtained from shale exposed in Shale Hills in sec. 10, T. 27 S., R. 18 E. This would place the locality in the upper shale marker of the Twisselmann sandstone member.

English, Walter A., Geology and petroleum resources of northwestern Kern County, California: U. S. Geol. Survey Bull. 721, pp. 21-24, 26-29, 30-35, 43-44, 1921.

The report includes an outline of the geology of northwestern Kern County including some revisions of the previous work by Arnold and Johnson. Data on several measured sections in the vicinity of Bitterwater Creek are pertinent. Geologic map.

Gester, G. C., and Galloway, John, Geology of Kettleman Hills oil field, California: Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 10, pp. 1161-1193, 1933.

A discussion of the correlation and terminology of Miocene formations in the San Joaquin Valley and the Temblor Range is presented. This article is given credit for the original publication of the term Santos shale. (See reference to May and Gilboe.)

Goudkoff, Paul P., Age of the producing horizon at Kettleman Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 15, no. 7, pp. 839-842, 1931.

Producing and non-producing formations in the Kettleman Hills field are assigned to the Monterey and Temblor formations. The article is pertinent to a general study of the stratigraphy of the San Joaquin Valley.

Kleinpell, Robert M., Miocene stratigraphy of California: Am. Assoc. Petroleum Geologists, pp. 1-450, 1938.

Fundamental basis for the recognition and establishment of age correlations of Miocene rocks in California is provided in this work. The comprehensive correlation chart and the bibliography are of particular interest.

May, A. R., and Gilboe, J. D., Foraminifera from the type section of the Temblor formation, Carneros Creek area, Kern County, California: Unpublished manuscript, Feb. 5, 1931. Copy on file at Branner Geological Library, Stanford University, California.

Reference studies indicate that this article contains the original usage of the terms Gould shale, Media shale, Carneros sandstone, Santos shale, and *Phacoides* reef. The Gould is listed as the basal member of the Monterey; the "Button bed", Media (upper shale), Carneros, Santos (middle shale), *Phacoides* reef (lower sandstone), and lower shale are listed as members of the Temblor of the type section. Credit is given H. G. Schenk for the term Carneros member as applied to the sandstone overlying the middle shale (Santos) at the type locality of the Temblor. The Carneros was previously called the "lower reef" by Arnold and Johnson, and the "main reef" by English.

Woodring, W. P., Stewart, Ralph, and Richards, R. W., The geology of the Kettleman Hills oil field, California: U. S. Geol. Survey Prof. Paper 195, 1940.

The authors present a detailed coverage of the Kettleman Hills area; their discussion of stratigraphic nomenclature is helpful in understanding current usage in the Temblor Range.

Geologic formations and economic development of the oil and gas fields of California: California Div. Mines Bull. 118, pp. 83, 118, 200, 247-252, 494-504, 1943.

Bulletin 118 contains a collection of papers and reports by authorities on the development of California's petroleum industry, the geology of California, and the occurrence of oil and gas, with descriptions of individual oil and gas fields. Also included is a glossary of the geologic units of California. Of special note is the paper by Paul P. Goudkoff, *Correlation of oil field formations on the west side of San Joaquin Valley*, pp. 247-252. The article contains statements of the age and correlations of the Santos shale, Agua sandstone, and Carneros sandstone members of the Temblor formation. In addition the following quotation is found on p. 251: "The lower Mohnian beds were cored and designated as the McDonald shale in some wells of the Alferitz area of Devils Den, in a deep well in South Belridge field, in a number of wildcat wells between South Belridge and Midway-Sunset, and in some of the Wheeler Ridge wells." The paper by Martin Van Couvering and H. B. Allen, *Devils Den oil field*, pp. 496-500, is also of interest. The Eocene, Oligocene, and Miocene rocks in the area are divided into a number of local members and formations for which new names are used. The massive upper Eocene sandstone exposed at the Point of Rocks is given the name of the locality.

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